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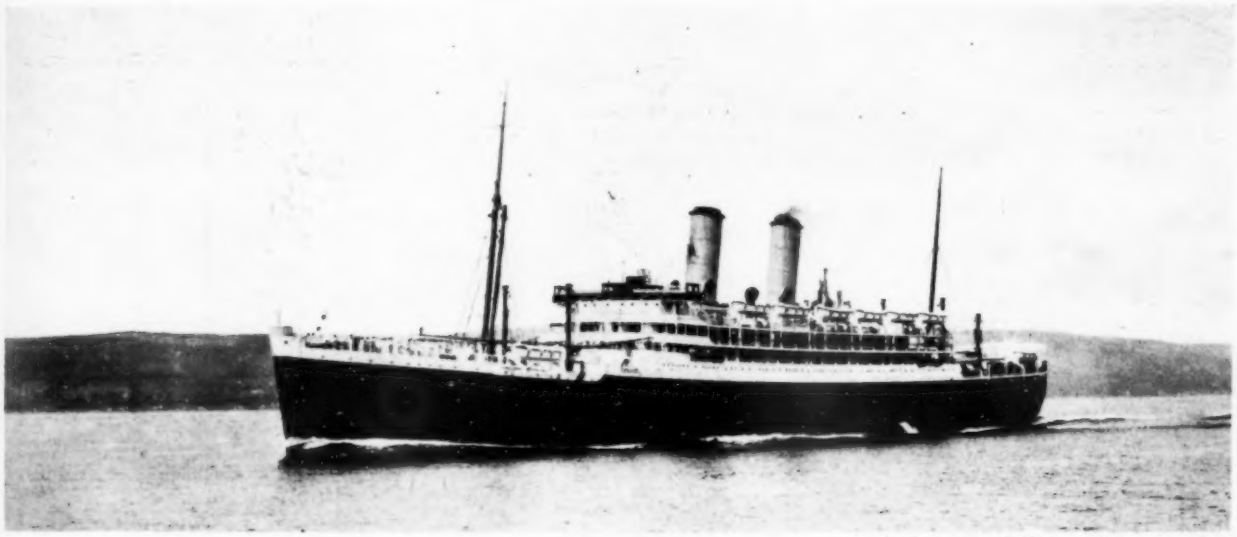


By Courtesy of Vickers Armstrong, Ltd.

T.S.S. "Orontes." A vessel recently constructed for the Orient Company.

Steels in Marine Engineering *and* Shipbuilding

By J. W. Donaldson, D.Sc.

Developments resulting from metallurgical research are becoming increasingly important in the selection of materials for high-speed ship construction. Reliable materials are available that reduce weight, provide extra space, and contribute to increased speed.

THE metallurgical side of marine engineering and shipbuilding is one which has become of increasing importance during the present century, and which has led to more rigid examination and inspection in the choice and selection of materials. This has resulted from the very marked developments which have occurred during this period both in shipbuilding and marine engineering. The papers published in the transactions of the Institute of Naval Architects, of any of the Institutes of Engineers and Shipbuilders, and of the Institution of Mechanical Engineers, show the extent of the progress which has taken place in both industries. A very brief and general summary shows that what is required is the construction of high-speed ships having as large accommodation for passengers or cargo, or both, as possible, together with the reduction of all unnecessary weight. Developments on these lines render necessary the serious consideration of all materials used, for it is only by the use of more reliable materials, both ferrous and non-ferrous, that weight can be reduced, extra space provided, and, to a large extent, extra speed attained.

Steel for Shipbuilding.

Since ships have been built of steel, mild steel has been invariably used in their construction, and has given satisfaction both as regards its strength and resistance to corrosion. In Admiralty construction, where weight has had to be reduced, steels of higher carbon content and giving higher tensile strengths have been in use for some considerable time (Table I). Such steels, however, have, in addition to extra cost, always required special care in working, such as drilling instead of punching, etc., so that their use in mercantile construction has been practically nil. Of recent years, however, new steels have been introduced into shipbuilding—steels which are generally referred to as high-elastic-limit steels.

The Admiralty specification for mild steel for shipbuilding is 26 to 30 tons per sq. in., and Lloyd's has a somewhat similar specification of 28 to 32 tons. In the case of commercial steels produced to the above specification it is found that the elastic limit or limit of proportionality is extremely variable, averaging about 8 tons per sq. in. A ship's structure should be as near as possible a perfectly elastic structure, and in designing a ship, the stresses to which it will be subjected in service have to be calculated, and have to be kept within the elastic range. It is obvious, therefore, that steels of low or variable elastic limit are not the most suitable for ship construction, particularly where a reduction of weight is required, hence the introduction of steels with a definite elastic limit.

Elastic limit steels are of two types—namely, those steels in which the ultimate stress is similar to mild steel, but which have a relatively high-elastic limit, and those which

have a high ultimate stress with a correspondingly higher limit of proportionality. The properties and application of these various steels in shipbuilding have been dealt with very fully in papers by Berry,[1] Service,[2] and Martin,[3] so that only a few general notes with regard to them are necessary.

The first type of elastic-limit steel mentioned above, is that developed by Martin. This is a heat-treated mild steel, and is specified to have an ultimate tensile strength of 29 to 34 tons per sq. in., with a limit of proportionality of 15 tons per sq. in. This steel, being a low-carbon steel, can be punched, sheared, and worked by ordinary shipyard methods without special precautions, and this is very important from the shipbuilders' point of view as regards cost of construction. The high-elastic limit which this steel possesses over ordinary mild steel is obtained by careful heat-treatment. Experiments have shown that this steel is no more liable to corrosion than ordinary mild steel, and no additional difficulties are experienced in the vibration of ships built with it. The use of 50% of this steel in the construction of a ship yields a saving of weight of 10%, which may mean anything from 300 to 500 tons, according to the size of the ship.

As regards the second type of elastic-limit steel, where the tensile strength is higher than that of mild steel, this comes under various specifications. The Admiralty specify a steel known as D quality, which has an ultimate tensile strength of 37 to 43 tons per sq. in., and a limit of proportionality of 17 to 20 tons. Lloyd's and British Corporation specify an ultimate tensile strength of 33 to 38 tons per sq. in., with an elastic limit of 15 tons, and allow a reduction of one-tenth in the scantlings below those permitted for a ship constructed of mild steel. Steels to the above specifications are not heat-treated steels, the higher breaking stresses and elastic limits being obtained by increasing the carbon content, having ingots as free as possible from blowholes and segregates, and controlling very carefully the finishing temperature when rolling. As regards the working of those steels, it is stated that they can be manipulated in the shipyard with only a slight degree more of care than is necessary when dealing with mild steel.

A summary of the specifications for those steels and the specification for high-elastic-limit mild steel, together with those of ordinary mild steel and Admiralty steels for comparison, is given in Table 1.

Mild steel with a copper content of 0·2 to 0·3% has also been used for ship plates in several cases, principally in the United States. It has been stated that copper-content steels are more resistant to corrosion than mild steels of similar carbon content, but evidence on this point is rather variable. On replacing a number of steel plates in the hull of the S.S. *Leviathan* after the war, it was found that the original German plates had resisted sea water much better than ordinary mild-steel plates. Examination of these plates showed the copper content to be 0·169%, but, owing to the fact that the steel showed a marked banded structure, whereby, after slight corrosion, low-carbon areas would be exposed to the sea water, rendered it doubtful whether the superiority was due to the copper content or otherwise. Corrosion experiments carried out in the laboratory by the American Bureau of Standards[4] have not confirmed the above, or shown that copper-content steels are more resistant to sea water than mild steel. Investigations, however, carried out in America by Bennet[5] have shown copper-content steels are more electro-positive than mild steels of similar carbon content (Table 2). When a ship is constructed, it is desirable that there should be no difference of potential between any parts of the hull, but if this is not possible one part should be made slightly electro-positive to the other. It has been suggested, therefore, on one hand, that in order to reduce rivet corrosion, rivets ought to be manufactured of copper-content steel; while on the other hand the use of copper-content ship plates has been advocated, as the corrosion on their large surfaces would be less likely to be harmful than the corrosion of the smaller rivet surfaces.

Copper-content steels, on account of their resistance to atmospheric corrosion and to hot gases, have also been recommended for the construction of decks, masts, and funnels.

TABLE 1.

SPECIFICATIONS FOR SHIP PLATES.

	Limit of Proportionality, Tons per Sq. In.	Yield Point, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation % on 8 in.
Admiralty	—	—	26–30	20
Admiralty H.T.	—	20	33–38	20
Admiralty H.H.T.	—	20	37–43	15
Admiralty D quality	17–20	—	37–43	17
Lloyd's	—	—	28–32	16
Lloyd's (elastic limit)	15	—	33–38	20
Elastic limit mild steel (Martin)	15	—	29–34	17–21

By Courtesy of Vickers Armstrong, Ltd., Barrow.
High-pressure Marine Boilers fitted in the S.S. "Kedah."

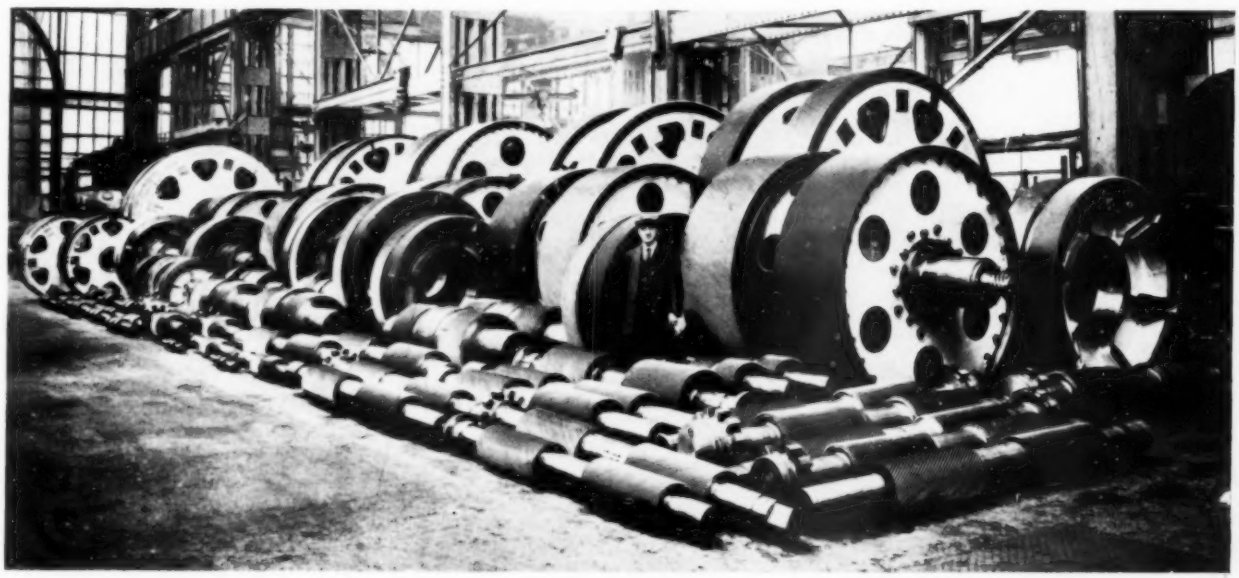
1 W. Berry, Institution of Civil Engineers, 1928.
2 T. M. Service, "Trans. Inst. Eng. and Ship (Scotland)," 1926-27; vol. 70, p. 320.
3 F. G. Martin, "Journ. West of Scot. Iron and Steel Inst.," 1928-29; vol. 36, p. 83.
4 "Bureau of Standards Journ. of Research," 1929; vol. 2, p. 431.
5 W. Bennet, American Society of Naval Architects and Marine Engineers, Nov., 1926.

Steel for Boilers.

In boiler construction, engineers have not encountered in marine work the problems which have developed as a result of higher temperatures and higher pressures in land power plants, and which have led to the use of various qualities of heat-resisting steels capable of retaining their strength at elevated temperatures. Machinery for Admiralty requirements and for mercantile construction is somewhat similar, but with the former, higher power is developed, and, consequently, it is in this class of work that special steels and alloys have been introduced in marine-boiler work, although only to a very limited extent.

In mercantile marine engineering, boiler temperatures and pressures have been fairly constant for many years, averaging 560° to 600° F. and 200 lb. per sq. in., and the type of steel used for shell plates and butt straps has been a low-carbon steel with a tensile strength of 27 to 32 tons per sq. in. This steel gives very satisfactory results, provided it is not subjected to severe cold work or mechanical deformation in the course of construction. In recent years, however, there has been a tendency to higher temperatures and pressures, although the limit attained has so far not exceeded 750° F. and 500 lb. per sq. in. If increase in weight is not to accompany increase in pressure it is necessary to consider the use of stronger materials of construction, with the result that steels having a tensile strength of 36 to 42 tons per sq. in. and a minimum elastic limit of 15 tons per sq. in., together with an elongation of 20%, are recommended for boiler shells and butt straps.

In the manufacture of steel for boiler tubes, which in service are liable to corrode externally and internally, and to distort and crack, endeavours have been made to produce steel as free from segregation as possible. It is considered that " non-segregated " tubes are less liable to corrosion, and so far as can be ascertained, results in service have shown their superiority. In America, boiler tubes have also been made of copper-content steel, it being claimed that this material is more resistant to corrosion. In Admiralty work, according to Eng.-Capt. Hope Harrison,[6] the special steels and alloys, " Cronite " (1% manganese, 14% chromium, 65% nickel), " Era " metal (21% chromium, 7·0% nickel), and " Brightray " (20% chromium, 80% nickel), have been used for supports for superheater tubes, and have withstood the high temperatures without twisting, corroding, or burning.



By Courtesy of Vickers Armstrong, Ltd., Barrow.

Group of Helical Gears.

TABLE 2.

ELECTROLYTIC EXPERIMENTS (BENNET).

Material.	Electrode Potential compared with Standard Calomel Electrode.
Zinc	1·274
Cast iron	0·650
Ordinary mild steel	0·604
Ordinary ship steel rivet	0·582
Plate of copper steel (0·23% Cu.)	0·558
Rivet of copper steel (0·27% Cu.)	0·556
Bronze from propeller	0·296
Hammered copper steel rivet, highly heated	0·595
Hammered copper steel rivet, heated to bright red	0·576
Hammered copper steel rivet, heated to cherry red	0·555

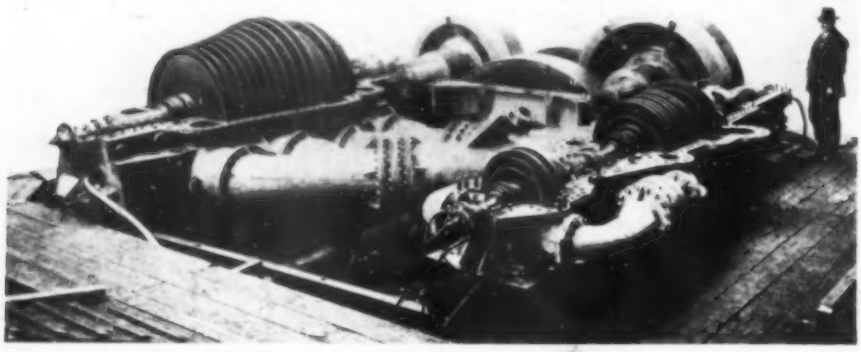
Turbine Gearing Steels.

During the last 10 or 12 years, the development of the marine steam turbine produced problems associated with the transmission of power from the turbine to the slow-moving propeller. Mechanical gearing, on account of its simplicity and efficiency was most universally adopted. In the early stages a single-reduction gear was considered sufficient to reduce the main shafting revolutions to those at which the propeller would attain its most satisfactory conditions, but it was soon felt that in order to obtain the full efficiency of the high-speed turbine a larger reduction ratio was necessary, and double-reduction gears were constructed. The adoption of gearing, and particularly of double-reduction gearing, led to the introduction of many new steels in marine engineering.

These steels were used in the manufacture of the pinions, wheel rims being of ordinary normalised steel, 30 to 34 tons ultimate tensile strength. In single-reduction gearing the pinion was usually of nickel steel (0·25 to 0·30% carbon, 3·5% nickel) heat-treated to give an ultimate tensile strength of 40 to 45 tons per sq. in., although nickel-chrome steels were also used. Similar steel was also used, at first, in the manufacture of double-reduction gear pinions, but owing to a large number of failures resulting in the fracturing of pinion teeth, it was considered necessary to use stronger and tougher steels, as it was thought that these

failures were in a measure due to the quality of the steel, and not altogether to the effect of inaccuracies in the teeth resulting from gearing cutting having a greater effect in double-reduction than in single-reduction gears.

Nickel-chrome steels (3·5 to 3·8% nickel and 0·8 to 1·2% chromium), nickel-chrome vanadium steels, and nickel-chrome-molybdenum steels (3 to 3·5% nickel, 0·8 to 1·0% chromium, 0·2 to 0·3% molybdenum), such as "Vibrac," came into general use. These steels for pinion use are oil-hardened and tempered to give an ultimate tensile strength of 55 to 60 tons per sq. in., a minimum elastic limit of 25 tons per sq. in., and an Izod impact value of 45 to 60 ft.-lb. The use of such steels, uniformly and carefully heat-treated, having segregation eliminated as far as possible, together with accurate gear cutting, has resulted in reducing very considerably the number of failures occurring in the teeth of double-reduction pinions.



By Courtesy of Vickers Armstrong, Ltd., Barrow.
Double-reduction Geared Turbine.

Turbine Steels.

The production of suitable material for turbine blading has been of considerable importance, and has also become more important in recent years, due to the development of the higher speed turbine. Failures in turbine blading are experienced in steam turbines, and are either due to corrosion or erosion, or a combination of both. In the high-pressure regions of the turbine where there is superheated steam, if a hard material is used, there is little danger of erosion, and corrosion ought to be at a minimum; but in the low-pressure regions there is a greater danger of both corrosion and erosion, due to the possible presence of water particles suspended in the steam.

TABLE 3.

MATERIALS FOR TURBINE BLADES (ADMIRALTY).

Material.	Stage of Turbine in which used.
Monel metal	H.P. and astern.
Hadfield's A.T.V.	H.P. and astern.
Firth's F.G.	H.P., L.P., and astern.
Firth's F.M.	H.P., cruising, and astern.
Firth's stainless	Astern.
Phosphor bronze	In all stages.
Brass	All reaction.

In reaction turbines the material in common use for turbine blades was 70 : 30 brass, or some other alloy of a similar composition; and in impulse turbines phosphor bronze (96·9% copper, 3·0% tin, 0·1% phosphorus) was used for all stages. Recent developments in the turbine have led to parts being more highly stressed, and this, together with the fact that bronze blades showed signs of considerable erosion, has led to the introduction of alloy steels. The extent to which alloy steels have been introduced for turbine blading in Admiralty construction is illustrated well by Captain Hope Harrison in his recent paper.[6] Table 3, taken from the paper, shows the various materials including alloys, steels, and the various stages in the turbine in which they are used. He also states that such alloy steels, having a yield point of 25 to 30 tons per sq. in., are reported to have shown no signs of erosion, although defects have developed due to shrouding and broken blades. Examination of these failures revealed no sign of the material being at fault, it being considered that omission of minor details in b ading and shrouding operations were more likely to be the cause, although design has also to be considered.

In mercantile construction, phosphor bronze was until recently, the material in most general use. It has, however, been replaced by 3·5 to 5·0% nickel steel, and by stainless iron (0·1% carbon, 12—14% chromium), and stainless steel (0·3% carbon, 12—14% chromium). The principal objection to a more extended use of stainless steels in this class of work has been that these steels are more difficult to work than non-ferrous materials and involve greater cost in machining and fitting. As these difficulties are overcome, their use will become more general, as results obtained from them in service have been satisfactory owing to their higher resistance to corrosion and erosion, and their stronger and harder nature.

Other parts of the steam turbine exposed to somewhat similar conditions as the blading, are partition blades or nozzle vanes cast into cast-iron or phosphor-bronze boxes. In mercantile marine engineering these are usually constructed of 3·5% nickel steel. Stainless iron or stainless steel, chrome-nickel steel (Firth's Staybrite), or Hadfield's A.T.V. alloy (10 to 15% chromium, 25 to 40% nickel, with smaller amounts of molybdenum, tungsten, or vanadium) have also been used successfully and their use is extending. The same materials have also been adopted in Admiralty construction, as will be seen from Table 4 taken from Capt. Hope Harrison's paper.[6]

TABLE 4.

MATERIAL FOR TURBINE NOZZLE VANES (ADMIRALTY).

Firth's F.M.
Hadfield's A.T.V. in cast-iron boxes.
Hadfield's A.T.V. in phosphor-bronze boxes.
Hadfield's A.T.V. nickel-plated and cast in phosphor-bronze boxes.
Firth's Staybrite.
Nickel steel.
Copper for astern turbines.
Gunmetal for astern turbines.

Steels for Oil Engines.

The development of the marine oil engine from the low-power, low-compression, low-speed early types to the modern high-power, high-compression, high-speed engines of to-day has set the metallurgist many problems to solve, for in this branch of engineering, as in others, increase in efficiency and power is demanded without increase in weight, and in order to obtain this, materials must be as reliable as possible. Conditions demand material with properties quite distinct from those used for units working at ordinary temperatures and pressures, conditions involving strength at high temperatures, resistance to the action of gases, and the influence of scaling.

The strength of materials at elevated temperatures is now indicated not by their ultimate breaking strength at a particular temperature, but by the load which they can sustain continuously. Steel, which at a temperature of 800° C., will, beyond a slight initial creep, sustain a load

6 J. H. Harrison, Inst. Naval Architects, April, 1930.

of 6 tons per sq. in. or more for an indefinite period without deformation provides the engineer with a very valuable material for high-temperature parts. Resistance to scaling and to the corrosive action of gases also determines the value of a steel working at temperatures ranging from 600° to 1,000° C., as well as its mechanical strength, and in recent years a number of heat-resisting steels have been developed in which the scaling effect is very much less marked than in ordinary carbon steels.

In the earlier types of marine oil engines, compression valves, starting air, and exhaust valves were made of ordinary carbon steels, but (owing to the erosive action of exhaust gases at high temperatures, and to the poor mechanical properties of the steel at those temperatures) these were soon replaced by valves having a cast-iron head on a plain or alloy-steel stem, or by valves of nickel, nickel-chrome steel, or stainless steel. Such valves have given fairly good service, and are still most generally used, but they are gradually being replaced by the special valve steels and alloys having high heat-resisting properties.

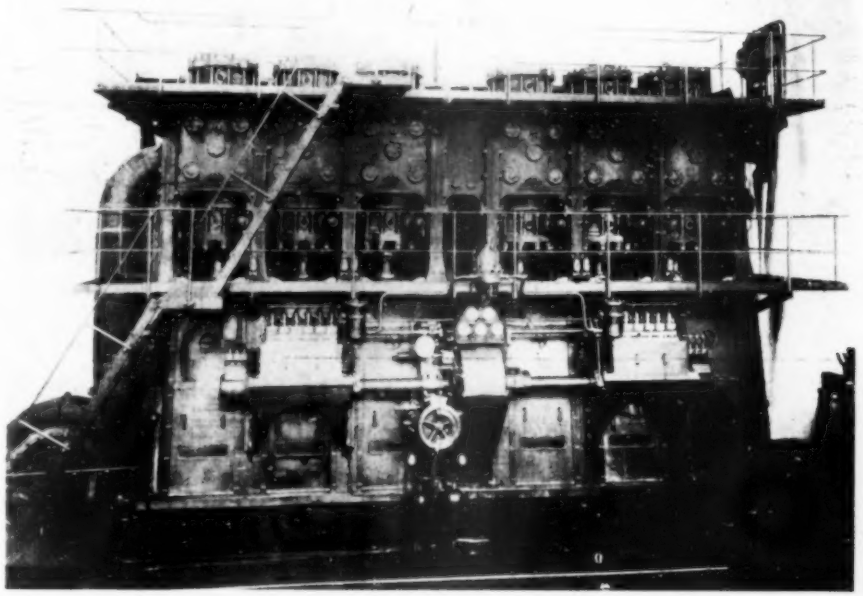
These special valve steels include various types of alloy steels. Among them are the silicon-chrome steels containing 3 to 4% silicon, 8 to 10% chromium, 0·4 to 0·6% carbon; the cobalt-chrome steels containing 5 to 6% cobalt, 12 to 15% chromium, 1·3 to 1·5% carbon; chrome-nickel-tungsten steel with 16 to 18% chromium, 7 to 9% nickel, 3 to 5% tungsten, and 0·4 to 0·6% carbon; and the nickel-chrome alloys having as high as 65% nickel, 15% chromium, and other special elements which confer special properties. The silicon-chrome steels do not show any marked increase in strength at high temperatures over the nickel-chrome steels and stainless steels, but their resistance to scaling is considerably more. The other steels and alloys, however, show a considerable increase in strength as well as a high-scale-resisting value; the value for the chrome-nickel-tungsten steel being about 100% greater than that of the chrome-silicon steels.

In other parts of marine oil engines alloy steels have also been used, but to a very limited extent, although their use is extending. In certain types of double-acting engines heat-treated nickel steel (3·5% nickel) has been used in the manufacture of piston rods, owing to its having a greater hardness and tenacity than ordinary carbon steel, whereby it can resist wear better and is more suitable for a part subjected to rapidly changing tension and compression forces. Heat-treated nickel steel has also been used in the manufacture of connecting rod bolts for similar reasons. Piston heads have likewise been made of this steel, and cylinder liners have recently been made of high-tensile toughened steel.

In the manufacture of fuel pump plungers, and gudgeon pins, case-hardening nickel steel is being used to an increasing extent. With such a steel, a very hard surface combined with fair strength is obtained, properties which are very essential in such parts. The use of chilled cast iron for cam pieces is also being gradually abandoned and its place taken by this steel.

In water spaces, where corrosion takes place to a fair extent, the use of stainless steel for tubing through such spaces is found to be beneficial. For similar reasons, nuts in water spaces are frequently manufactured either of stainless iron or stainless steel.

Alloy steel springs are also used to a limited extent, particularly spiral springs for high-duty parts. These springs are usually manufactured of tungsten steel or tungsten-vanadium steel. Special alloy steels are also used for spray nozzles.



By Courtesy of Vickers Armstrong, Ltd., Barrow.
Vickers M.A.N. Diesel Oil Engine.

Steels for Other Parts.

Stainless steel is practically the only steel which has been used in the manufacture of condenser tubes for marine work, experiments with stainless-steel condenser tubes having been undertaken by the Admiralty. This steel has also been used in the manufacture of ship propellers to a slight extent. Propellers for ice-breakers have been manufactured of 3 to 3·5% heat-treated nickel steel on account of its toughness.

In auxiliary machinery, stainless steel is also frequently used in the manufacture of centrifugal-pump spindles, and according to Archbutt[7] nitrited aluminium-chrome-molybdenum steels (1·25% aluminium, 1·5% chromium, and 0·2% molybdenum) have been utilised in marine-engine auxiliaries for such pump parts as piston rods, plungers, crossheads, rod guides, valve seating, spindles, and sleeves. For electrical auxiliary machinery, rolled sheets of special magnetic steel are used in the construction of dynamo and motor frames and casings in place of heavier and more expensive steel castings. Special non-magnetic steels (nickel steels) are also required for certain electrical parts.

Conclusions.

The foregoing is a general summary and review of the uses to which special and alloy steels are being used in shipbuilding and marine engineering. In many cases their use is limited and will remain so, but in others, particularly in oil-engine construction, their use will be largely extended. The principal objection, at present, to a more extended use is the extra cost, not only for material but also in machining operations. Economy in maintenance as well as first costs has also got to be considered, and this, together with the additional security and reliability obtained by using higher-grade material, must, in the near future, lead to a very considerable development in the use of special steels and special alloys.

7 S. L. Archbutt, "Trans. Inst. Marine Engineers," 1930; vol. 42, p. 295.

Magnesium Alloy Castings

By E. Player, M.Inst.M.

The author, who gave a lecture on this subject at a combined meeting of the London branches of the Institute of Metals and the Institute of British Foundrymen on December 11, discusses briefly the characteristics of magnesium alloys and some of the principles involved in the production of sound castings.

IN the last ten years the production of magnesium on a commercial scale has been developed to such an extent that the alloys of the metal are available at prices attractive to the engineer.

There are obvious attractions for the designer and constructor in a metal having good physical properties and the low specific gravity of 1·83.

Subjoined table shows the strength figures and mass-strength ratio of the elektron magnesium alloys, compared with other metals in common use. It will be noted that mass-strength ratio is higher than any other material in the table.

TABLE III.

Mechanical Properties of Sand Castings, Tons/Sq. In.

Material.	Yield Point.	Ultimate Stress.	Elongation, %.	Brinell Hardness.	Spec. Gravity.	Mass-Strength Ratio, Ultimate Stress, Sp. Gr.
Elektron A.Z.G.	6–7	9–11	4	50–60	1·82	5·5
Aluminium L 5	6–7	9–11	3	50–60	2·95	3·4
Aluminium L 11	7·2	9–10	2	60	2·85	3·33
Alumin. Sil. (Mod.)	—	12	8	—	2·66	4·5
"Y" Alloy as cast	10	11·9	1·5	89	2·80	4·2
"Y" Alloy heat-treated	13·9	14·7	1	100	2·80	5·25
70/30 brass ..	6·5	13–15	30–40	50	8·6	1·7
Cast steel ...	17–19	28–32	10–12	150	7·8	3·35
Cast iron	—	11–15	Nil	—	7·2	1·8
Malleable cast iron	13–17	20–24	6	150	7·2	3·1

As a consequence of these valuable properties, the use of elektron alloys in casting form has greatly increased in the construction of transport vehicles, electrical machinery, moving parts in high-speed production machines, etc.

Principles of Casting Production.

Alloy Composition.—The following is an outline, necessarily brief, of the principles and practice of casting production.

Magnesium having a strong affinity for oxygen, it was necessary in selecting alloying metals to give the best physical properties in the alloy, to choose metals as nearly placed to magnesium in the electro-chemical series as possible. Otherwise the alloys would be liable to rapid corrosion in contact with damp atmospheres. The elektron alloy commonly used for castings, known as A.Z.G., contains 3% zinc, 4% aluminium, 0·35% manganese, remainder magnesium. The addition of a small percentage of manganese has been found greatly to improve resistance to corrosion.

Melting.—Wrought iron or steel crucibles are used, as magnesium does not alloy with Fe.

The casting alloy melts at 635° C., and unless protected, will oxidise rapidly in the molten state, the resultant casting being defective and contaminated throughout with oxide and nitride inclusions.

To overcome this difficulty, a flux has been developed, the basis of which is magnesium chloride. This flux is thoroughly stirred into the fluid metal, dissolving oxides, etc., in the process, and leaving the metal thoroughly clean. The surface of the metal is then covered with another layer of flux, which becomes viscous and protects the surface from further attack.

Fig. 1 shows relative positions in crucible of metal and flux after stirring and covering. In pouring, the viscous covering is held back with a skimmer, and is so tough that none enters the mould with metal.

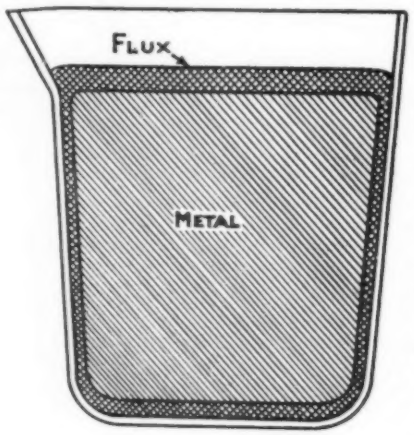


Fig. 1.

Moulding.—If molten magnesium is poured into a green-sand mould there will be a violent reaction due to decomposition of the water in the sand by the magnesium. A dry-sand mould will also be attacked to a lesser degree, due to remanent moisture and the water of hydration in the clay bond.

This obstacle to the production of sound castings has been overcome by a patented process, by which a small proportion of powdered sulphur and boric acid is mixed with the sand. The contact of the molten metal with such sand produces sulphur vapour, which has no affinity for magnesium, and entirely inhibits any reaction between the metal and the moisture and silica in the moulding sand.

Fig. 2 is section through ingot made in sulphur sand. Note that layer next the ingot has had sulphur vaporised almost entirely away, the vapour having condensed in a layer farther away from ingot, which is much richer in sulphur than the general body of sand.

Generally speaking, moulding practice follows the same

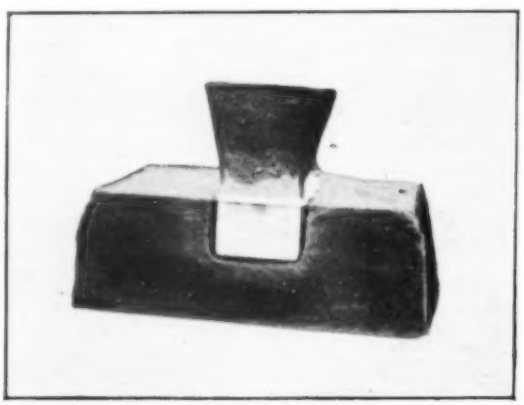


Fig. 2.

lines as in an aluminium foundry with the exception already mentioned. It is important to avoid all agitation of metal in the mould, and therefore, wherever possible, castings should be poured from the bottom, to ensure tranquil filling of mould, the crucible held close down to pouring head, to avoid splashing.

A typical casting produced on a commercial basis is shown in the illustration, Fig. 3.

(*Continued on page 52.*)

METALLURGIA

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METALLURGIA
THE BRITISH JOURNAL OF METALS.

CURRENCY PROBLEMS AND WORLD TRADE.

THE year 1930 is drawing to a close, and were trade analyses to be made in the various countries, there is not one that—with the possible exception of France—would show a credit balance on the year's work. It is ending just a little better than when it started, but depression is still world-wide. This country is spending over £100,000,000 a year in the relief of unemployment without getting any assets in return. Economic rather than politic considerations are involved. Apart from the merits or de-merits of protection, there is the phenomenon of so-called free-trade England suffering as acutely as highly protectionist America, with its unparalleled natural resources. The statement frequently made that the causes of the depression in this country are obsolete equipment and inefficient organisation and management are based on false theories, and it is wrong to state that foreign industrialists are more adaptable than British industrialists. Nor has there been over-production, but rather enforced under-consumption. This country is too self-critical, and self-criticism can be, in effect, as much a vice as a virtue. The sapient pessimists who declaim against the coal industry, the iron and steel industry, the railways, and the other pivotal industries, as being non-progressive, have not intelligently examined the industries of competing countries, nor profited by the lessons of history. A knowledge of industrial history, and the gift of prescience, might prove to them that we have reached a recurring point in the trade cycle. The present depression is not unprecedented. The period 1816 to 1843 was one of black depression and distress, but there were fitful gleams of light at those times when prices were rising. Then, after thirty years of unparalleled progress, the economic structure was reduced to disorder in 1873, and there was trade depression until 1896. It should be profitable to consider what factors proved remedial in previous periods of depression, and that light is penetrating the clouds now is evident by the increasing attention that is being given to what may be termed the money question. Industrialists are asking if the depression is not attributable to stupid international financiers, and, if so, is it too extravagant a prospect to hope that the world's producers may combine to smash the gold corner?

Can it be postulated that the primary, if indirect, cause of the world depression was the late war? Can the last ten years of depression not be assumed to be the logical outcome of war debt arrangements? Is not the machinery of finance so delicate and so sensitive to artificial restrictions that interference with the interchange of goods between countries, for punitive purposes or for debt redemption, may cause as much suffering to the creditor nation as to the debtor nation. It is surely beyond economic argument, and is a matter of historical teaching. The instrumental factors in raising industry from the depression of 1816 to 1843 were the discoveries of alluvial gold in California and Australia, and the depression which ended in 1896 was ended by the discovery of the cyanide gold extraction process and the opening of the Rand and Klondyke mines. At other periods, depression in this country has been traceable to artificially induced gold scarcity. The influence of gold on trade and commerce was emphasised recently by the discovery of the Merionethshire gold belt, but Professor Henry Louis disposed of the hope of salvation from this source by stating in his report that gold mining in Wales would be too speculative an undertaking on which to expend public money. The statement is made above that former trade depressions have been traceable to artificially induced gold scarcity, and if this is as incontrovertible as it appears to be, is it not reasonable to deduce that the hoarding of gold by the United States of America and France, who sucked—is there a better word?—into their vaults no less than £30,000,000 worth of gold in 1929, or more than the whole output of the year, is one direct cause of the world depression? The reason for the American hoarding is, of course, that British and other European debts have been funded on a gold basis. In the first week of this month the United States of America imported £600,000 worth of gold, chiefly, it is said, from Latin-American countries, and it is considered likely that 1930 will end with a net gain for her of £55,000,000. Actually, over 92% of the world's gold is held by the United States and France. Yet the wealthiest country in the world, whose engineering shops and iron and steel works are claimed to be super-efficient, has a grave unemployment problem, and in every city there are food queues and widespread misery. The release of gold by America and France would result in an immediate increase in prices and revival in trade. But the gold held by the two countries is as useless as a miser's hoard, because there is no equivalent of credit.

The United States of America would be wise to consider whether its hoard of gold is definable as wealth, if it is clogging the life-stream of the country. It is now a principal exporting country, but its potential customers, owing to its cupidity, cannot afford to buy from it. The influence of gold on world commerce is indisputably all important, and America should not forget that in one of its greatest financial crises, that of the autumn of 1907, the abnormal demand for gold threatened to paralyse the international money market, and the task of providing the required gold fell to England, which drew the gold required for New York from seventeen countries. This she was able to do because of her long-standing and deserved reputation for international honesty in financial deals. No country but England was willing to send gold direct, and so this country shouldered the whole responsibility. In England's desire to remain honest, and certainly more from purism than from wise policy, it deflated its currency after the war. It might have adopted a more selfishly-wise policy. A writer in a Sunday paper a week or two ago said: "France is making productive use of her gold in fortifying her legal tender currency, and so qualifying for that complete financial control of all nations and world trade which a legal tender fully covered by gold will ultimately give to her." Great Britain prefers principle to policy, and something more than a hoard of gold is necessary to make a nation pre-eminent. France's cupidity may arise from her fear of her neighbour Germany. It is much that attention is at last being concentrated on finance, and that currency experts are taking the place of industrialists in the dock of public opinion. At no distant date good workmanship will again be the influencing factor in the world's markets, and it will be proved that this country has not ceded its proud position of being the premier industrial nation.

MACHINE TOOL DESIGN.

DURING recent years, many factors have been operating against what was recognised as standard practice in machine-tool design. The progress made in the development of high-duty alloys, and the need for increased speed of production, necessitated considerable research with a view to improving high-speed steel and other cutting materials of exceptional character. Considerable success has attended the effort to improve the cutting qualities of various materials, but higher cutting speeds have imposed duties upon many machines that they were never designed to bear. To be effective, progress in engineering must embrace every operation and all forms of equipment, from the raw material to the finished product, and the machine tool has an important function to perform. Few machine-tool designers anticipate the trend of modern developments, with the result that few machines are capable of giving maximum efficiency from new cutting materials.

The fact that the majority of machines now operating in machine shops cannot be speeded up and yet maintain rigidity in operation, is retarding the full utilisation of the super-cutting materials available, and is slowing the rate of production. To meet modern needs, it is imperative to modify existing designs or to design new machines to provide greater rigidity at cutting speeds in keeping with the advance in cutting materials.

IRON AND STEEL SPECIFICATIONS.

A STEP in the right direction is envisaged by the decision, taken at a recent council meeting of the British Engineering Standard Association, to appoint an Iron and Steel Industry Committee. This decision which will undoubtedly have a far-reaching effect in the iron and steel industry in this country, was arrived at primarily as a result of a resolution passed by a fully representative conference, held at the Institution of Civil Engineers in October last, which was presided over by Sir William Larke, K.B.E., Director of the National Federation of Iron and Steel Manufacturers. Representatives from upwards of sixty organisations and Government departments attended the conference; many of the leading engineers and technicians interested in the use and production of iron and steel were present in a representative capacity, and these were qualified to represent fully both users and producers as well as research and technical institutions.

The object of this Committee is to investigate the requirements of specifications for iron and steel with a view to their reduction. All who are interested appreciate the need for simplifying specifications, not only to remove anomalies at present in operation, but to meet modern requirements. There is ample room for a considerable reduction in the number of specifications, and some modifications to existing ones will be necessary. There can be no question that rationalisation of this kind is long overdue; it would certainly meet a general need, and would, in a measure, contribute to high-productive efficiency, since it would reduce the number of specifications and increase the purposes for which they could be applied. It is obviously essential that users and producers should co-operate to secure a result in keeping with modern conditions.

At present, differences exist between specifications for similar service, and the reduction of these anomalies, as well as the modification of other specifications to give them increased scope, could only be secured by such co-operation as would be rendered possible by the appointment of an Iron and Steel Committee, through the operations of which it may be confidently anticipated that productive efficiency will ultimately be increased. This would inevitably result in the reduction of cost for a given service, and would provide a stimulus to the development of capital enterprise, which could not fail to have a substantial effect, as an important factor in restoring prosperity not only to the industries concerned, but to those dependent upon them.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

1931.
Jan. 2. Extra general meeting. "An Experimental Investigation into Induction Conditions, Distribution, and Turbulence in Petrol Engines," by S. J. Davies, Ph.D., M.Sc.

INSTITUTE OF METALS.

1931.

BIRMINGHAM SECTION.

Jan. 6. "Tubes."

LONDON SECTION.

Jan. 8. "Extrusion," R. Genders, M.B.E., M.Met.

NORTH-EAST COAST SECTION.

Jan. 13. "Copper-silicon Alloys," W. B. Goudielock.

SCOTTISH SECTION.

Jan. 12. "Chromium Plating," J. G. Roberts.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

1930.
Dec. 19. Informal meeting, 7-15 p.m. "Are we justified in using steel and other materials of foreign manufacture in the British engineering industries?" Subject to be introduced by E. Leslie Champness M.Sc., M.B.E.

INSTITUTION OF WELDING ENGINEERS.

1931.
Jan. 8. Paper by H. D. Lloyd, Esq., and J. S. G. Primrose, Esq.: "The Use of Pure Iron Electrodes for Welding Cast Iron." At the Institution of Mechanical Engineers, Storey's Gate, St. James' Park, S.W. 1.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

1931. BIRMINGHAM BRANCH.

Jan. 14. Visit to works of Messrs. F. H. Lloyd and Co., Ltd., Wednesbury.

LANCASHIRE BRANCH.

Jan. 3. "Some Impressions of American Foundry Theory and Practice." J. G. Pearce, M.Sc., M.I.E.E., Birmingham.

Jan. 10. Annual dinner, Grand Hotel, Manchester.

LONDON BRANCH.

1930.
Dec. 19. Annual dinner.

1931.
Jan. 15. "Cupola Malleable Cast Iron." H. H. Shepherd.

MIDDLESBROUGH BRANCH.

Jan. 9. "The Manufacture and Properties of Malleable Castings." J. K. Smithson, Middlesbrough.

SHEFFIELD BRANCH.

1930.
Dec. 19. "A New View of the Composition and Structure of Cast Iron." J. E. Fletcher, M.I.Mech.E., Dudley.

1931. WALES AND MONMOUTH BRANCH.

Jan. 10. "An Indian State Railway Foundry." C. A. Howe, Bombay (at Cardiff).

WEST RIDING OF YORKSHIRE BRANCH.

Jan. 3. "Mould and Core Drying." Paper by G. E. France. At the Technical College, Bradford. 6-30.

INSTITUTE OF MARINE ENGINEERS.

1931.
Jan. 13. "The Electrical Equipment of a Modern Ship." Mr. J. E. Allan.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.

Jan. 7. *Sessional meeting.* Mr. C. G. Heys-Hallett, M.A., "Notes on the Theory of Radiant Heating."

INSTITUTION OF AUTOMOBILE ENGINEERS.

1930. BIRMINGHAM CENTRE.

Dec. 17. Paper: "Machine Tools from the Manufacturing Users' Point of View," by Mr. H. C. Armitage, of the Austin Motor Co. At the Engineering and Scientific Club, Queen Street. 7-30 p.m.

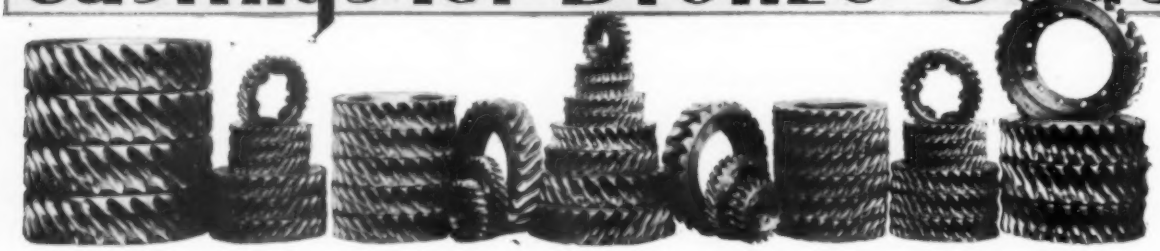
SCOTTISH CENTRE.

Dec. 22. "Trends in the Transmission." Paper read by Dr. H. E. Merritt. At the Institute of Engineers and Shipbuilders, 39, Elmbark Crescent, Glasgow. 7-30 p.m.

1931. BRISTOL CENTRE.

Jan. 8. "Light Alloy Piston Development." Paper read by Mr. E. V. Pannell. At the Merchant Venturers' Technical College, Unity Street. 7 p.m.

Castings for Bronze Gears



* By Francis W. Rowe, B.Sc., M.I.M.M.

During recent years the production of bronze castings for gear-wheels has developed into a highly specialised art, and the author proposes to consider the salient features in their production in a series of articles of which this is the first.

THE constant desire of designers to secure an increasingly lower weight per horse-power, with the manifold advantages thus accruing, has led to a constant increase in working stresses. This means that greater care and thought have to be expended on the castings nowadays, otherwise failures will inevitably occur in castings which would previously have functioned satisfactorily.

One of the largest uses for bronze gear castings is in the production of worm-wheels for heavy vehicle drives. Practically all modern heavy automobile vehicles for transport and passenger work have the final drive transmitted by means of worm-gear due to its quiet running, high efficiency, and the small centre distance required for transmitting heavy powers.

The worm-gear, as usually made for heavy stresses, consists of a casehardened steel worm running with a bronze worm-wheel. This combination gives the lowest coefficient of friction compatible with adequate strength in the parts. Less highly stressed gears have a worm of direct hardening material, but this cheaper method of production does not give as low a coefficient of friction, thus the temperature rise in the case is higher and the wear on both members greater.

Modern worm-gears incorporate an alloy case-hardened steel worm, ground on the teeth after hardening, with a surface hardness of from 75–85 scleroscope (Rockwell hardness C57–C63), and polished before putting into service.

Composition of Bronze for Worm-gear.

Although the analysis of a bronze, *per se*, is no criterion as to its suitability for the duties, it is, of course, essential that this be right. The composition of the bronze used by various manufacturers has been narrowed down in recent years to within fairly close limits. Variations within these limits are permissible, dependent on the mode of casting employed and the particular duties involved.

The analyses employed lie, in the great majority of cases, within the following range :—

Tin	10·0—13·0%
Phosphorus	0·10—1·3%
Lead	Nil — 0·5%
Zinc	Nil — 2·0%
Nickel	Nil — 2·0%
Copper	84·5—89·0%

As mentioned above, more important than the actual analysis of the bronze are the raw materials used, the melting practice, and the methods used for moulding and casting the gears.

* *Chief Metallurgist, David Brown & Sons (Huddersfield) Ltd.*

Selection of Raw Materials.

There is no question whatsoever that the production of a really satisfactory worm-gear bronze calls for materials of high purity, carefully alloyed. Since copper constitutes 84·5—89·0% of the finished alloy, the purity of this should be carefully watched.

The most suitable material for heavy charges is electrolytic wire-bar ingot of 99·90% purity and above. Selected grades of B.S. ingots can also be used with satisfactory results, though certain brands, although conforming to the B.E.S.A. standard for this material, have been found to be noticeably inferior to wire-bar ingots for this particular work.

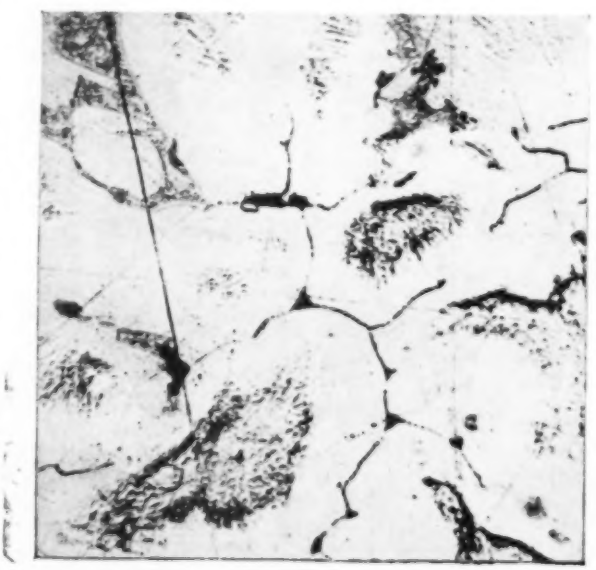


Fig. 1.—11% *Tin Bronze* × 400 *dias. Weakness due to Inter-crystalline Films.*

A good deal of misapprehension appears to exist also on the subject of " secondary " or scrap copper for bronze. Such material as copper wire, whether tinned or bright, trolley wire, etc., is distinctly unsuitable for this class of work. The author is aware that many bronze foundries utilise such material (sometimes exclusively) for this class of casting, but such a practice is to be strongly deprecated. Since the material itself is of high initial purity, and the price tempting, many founders lull themselves into

considering secondary electrolytic copper of equal value to electrolytic ingots; but this is far from being the case.

With copper wire, on account of the very large surface area exposed, considerably more oxidation takes place in melting than with ingot material, and the gas absorption is correspondingly higher. The two most fruitful causes of unsound or weak bronze castings are oxidation and gas absorption during melting, and every care must be taken to avoid these troubles. Tinned copper wire is even worse than bright copper wire, as the larger portion of the tin coating is oxide long before the copper is melted.

The author appreciates that the oxidation could be avoided if a truly neutral atmosphere were present during the whole of the melting period, but, as can be easily demonstrated, such an atmosphere is a virtual impossibility in all commercial types of melting furnaces, and, in fact, undesirable.

Trolley wire or burnt copper wire is a particularly deleterious material for high-class bronze, as the material is initially coated with oxide and other corrosion compounds. In the case of trolley wire also the practically universal practice nowadays of using copper cadmium wire renders this material still less suitable as a basis for bronze castings. Such material as fire-box copper, on account of the high arsenic content and its burnt and often decidedly sulphurous nature, is quite useless for high-grade worm-wheel bronze.

Regarding the tin used, this should be Banka or Straits tin or the highest grades of English refined, of purity not less than 99·80%.

Phosphor copper from reputable makers should be used, and founders should be very cautious about certain Continental parcels offered from time to time, as these—whilst containing their full quota of phosphorus—sometimes possess deleterious impurities.

In short, the raw materials should be purchased on a basis of quality and not price. To secure a bronze with maximum physical propertes, it is very essential to start right. Making high-grade bronze is one of those processes which justify the old proverb relative to sows' ears.

Typical examples of gaseous absorption and oxidation troubles are shown in Figs. 1 to 3, taken from various grades of phosphor bronze.

Melting Practice.

As will have been gathered from previous remarks, melting practice plays an important part in bronze production, and is a phase which founders, who have not the facilities for regularly testing their product, are apt to neglect.

The primary objects, with any type of furnace, are to melt the metal as rapidly as possible, and with the minimum oxidation and gas absorption. The means to achieve this end vary naturally with the type of furnace, and the nature of the fuel, but one essential common to all types is that the furnace or crucible should be thoroughly preheated to a temperature of 1,300° C. before the charge is introduced.

The older types of crucible furnace, either the pit type or forced draught tilters, are being superseded for bronze founding, by the coke or oil-fired non-crucible type.

Whilst the coke-fired crucible furnace gives satisfactory results from a metallurgical point of view, it is an uneconomical furnace from many respects. Primarily, its thermal efficiency is extremely low, seldom above 5%, and in many cases less. A coke consumption of 30 lb. per 100 lb.—a very satisfactory consumption for this type of furnace—represents a thermal efficiency of 6·6%. The crucible cost per ton of metal works out very high. Usually the cost of crucible casts are between 16 and 24% of the total melting costs, and the process does not lend itself to great rapidity or volume of output.

A 400-lb. crucible furnace will take, after the first heat, 1¾ to 2 hours to melt a charge, whereas an oil-fired reverberatory furnace will melt this amount in 30 mins. comfortably.

The major portion of the melting plant in foundries with which the author is associated consists of coke-fired reverberatory furnaces. The average time taken for ½ ton heat of ingot metal is 35 mins., and for a 24-cwt. heat of ingot metal, 55 mins.

Fig. 2.—Inter-granular Films, due to the use of poor raw materials or to improper melting. Phosphor Bronze × 200 dias.

The reverberatory furnace, with oil-firing, or coke-fired with forced draught, is particularly suitable for bronzes and gunmetals, and with experience and care a high quality metal with low losses can be produced.

The electric furnace, whilst undoubtedly the furnace of the future, has not yet succeeded in getting a firm foothold in this country. Almost 80% of the bronze foundries in the States operate electric furnaces—chiefly of the rocking arc-type,—and the results obtained are very good. One

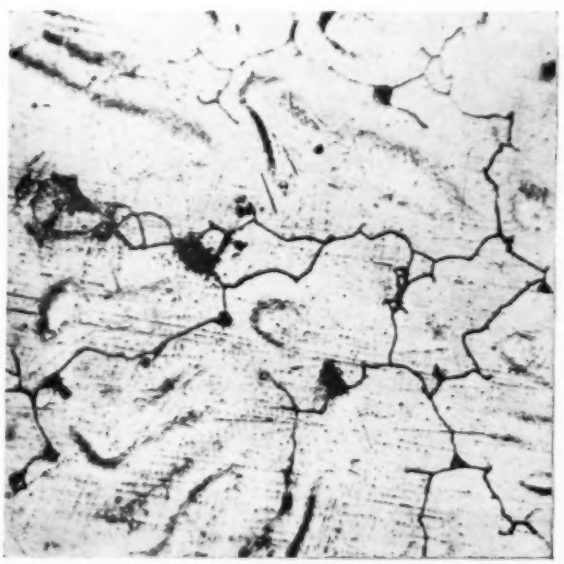


Fig. 3.—Sample of Worm-wheel Bronze × 400 dias. Gassed condition of metal due to poor melting practice.

of the chief obstacles to the greater exploitation of this type of furnace in this country is that such furnaces are single-phase and supply authorities in this country look very unfavourably on large out-of-balance loads. No

doubt, however, as the demand for this type of furnaces increases, supply authorities will make suitable arrangements to cater for it. The electric furnace for bronze melting, as with any other type of electric furnace, involves a large capital outlay, but the general trend of American opinion is that the overall melting costs (particularly taking into consideration melting losses) justify their popularity.

In melting bronze for high-grade work, care needs to be taken of the method of alloying. Cuttings and light scrap should not be melted with ingot metal. There are several reasons for this. Such light scrap should be melted separately under different conditions, and the resulting metal ingotted for use (after analysis) in correct proportion in the metal for casting.

When melting for casting, the ingot copper and ingot metal should be melted first in the correct atmosphere, and superheated to just above casting temperature. Any deoxidation and slag removal should next take place, and the charge suitably stirred or rabbled. The phosphor copper having been added, the tin should be put in last, and, after again gently stirring the metal, drawn or tapped

Fig. 4.—Inter-granular Fracture of Phosphor Bronze, due to bad melting × 4.

for casting. Whilst metal should not be overheated, as under such circumstances gas absorption and volatilisation of phosphorus and tin occurs to a harmful degree, a certain degree of superheat is essential to assist any trapped impurities to rise to the surface by lessening the viscosity of the metal.

The question often arises as to whether weak or unsound bronze is due to unsuitable raw materials or wrong melting methods. If any doubt exists as regards either, then there is no royal road to distinguish between the two evils, as in many cases the nett result is the same. It cannot be too strongly reiterated that an ordinary chemical analysis alone is no guide as to whether the foundry practice has been in error or not in these two essentials. Such an analysis, as usually conducted, fails to record the gas content or the presence of oxides.

As a striking example, the illustration, Fig. 4, shows a typical case of a complete intergranular fracture in a bronze of high purity, but most probably spoilt by poor melting practice. The material was phosphor bronze of a similar analysis to that often used for worm-gear, and these completely intercrystalline breaks were obtained with very low stresses.

The fracture of a bronze casting, given a knowledge of the composition and a correct appreciation of the method by which it was cast, often forms a useful guide as to the character of the material. Incidentally, the fracture test is considerably more discriminating in a sand casting than in any other, and high tin and high phosphorus contents may mask deleterious characteristics so that judgment should be exercised in assessing the character of a bronze on fracture alone. Nevertheless, a weak, oxidised, or gassed bronze very often shows specks indicative of partially intergranular cleavage on breaking. Such specks vary from a distinctly golden colour to deep red, and in very bad cases the fracture presents a heterogeneity of colours.

In some cases this discoloration may be due to "draws"—liquid shrinkage flaws,—but the nett effect is the same whatever the cause.

Such material has a tensile strength varying from 4 to 12 tons per sq. in., dependent on the character or size of the blank or test-bar on which tests are made, instead of a strength of from 17 to 24 tons, which can be obtained from material of identical analysis, properly made. Unfortunately, the appearance of such a casting, either in the rough or machined condition, gives no indication of its weakness or unsoundness, and the only way either a manufacturer or purchaser can assure himself of the quality of the material is by frequent and thorough tests.

It is also unfortunate that many purchasers and engineers are ignorant of the pitfalls that lie in the method of buying bronze castings on appearance or analysis alone. The author had a case brought to his notice recently, where a very large manufacturer of worm-gear had bought castings on this basis, and although the castings satisfied his specification regarding analysis, he was involved in a colossal loss through service failures, due to unsound metal of the character indicated above.

(Subsequent articles will deal with the various modes of casting worm-wheel blanks, and the effect of these and varying composition on physical properties and service results.) *(To be continued.)*

Magnesium Alloy Castings.

(Continued from page 46).

Machining.—For most operations the practice usually followed in machining aluminium may be followed for magnesium alloys, although, where suitable machines are available, and with correct cutting angles on tools, considerably higher cutting speeds may be attained, resulting in improved finish and reduced costs.

Very fine cuts should be avoided, as wearing tools unduly and giving rise to magnesium dust, which may be ignited through tool sparking or by contact with a naked light. With reasonable precautions, however, such

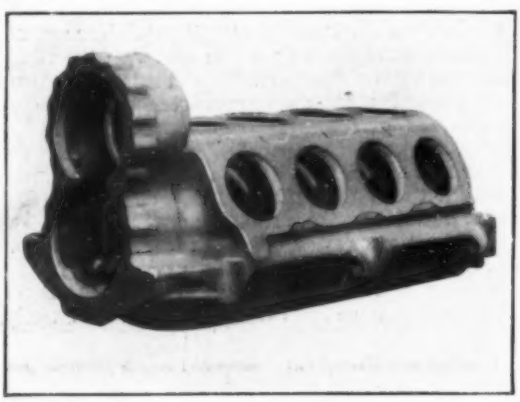


Fig. 3.

troubles are easily avoided, and something like 45 tons of elektron castings are being produced and machined every month in England alone. Taking into allowance the low specific gravity of the metal, and the relatively short time it has been commercially available, it will be seen that the material has progressed at a rate probably quicker than any of the metals that become readily available to man.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part III.—Melting Furnaces.

This discussion deals with furnaces for use in melting aluminium and its alloys prior to pouring rolling ingots.

MANY different types of furnaces have been used in practice for melting aluminium and its light alloys prior to pouring into rolling ingots. In fact, almost every type of furnace which has found application for melting aluminium alloys in foundry practice and in secondary work has also been used for melting in the rolling mill. As is well known, wide differences of opinion are held as to the most suitable types of furnaces for melting in various branches of the aluminium industry. The different types of furnaces so far used in practice for melting aluminium and its alloys include the following: Pit furnaces, stationary and tilting-crucible furnaces, stationary and tilting iron-pot furnaces, open-flame tilting furnaces of several designs, stationary and tilting-hearth furnaces (so-called reverberatories), and electric furnaces of several designs. Aluminium and aluminium-alloy melting furnaces have been previously discussed in detail by the writer in various papers[4] [5] [6] and other published works.[9] [17]

Furnaces of small capacity, like the pit and crucible types, still find application in some rolling mills, particularly those having small and irregular output. Iron-pot furnaces have never been favoured for melting prior to pouring rolling ingots, but the tilting type has been used in some plants. So far, the stationary-hearth furnace has been used most widely, the tilting-hearth and barrel-shaped open-flame tilting furnaces being employed to a less extent. Electric furnaces of the metallic-resister type have made some headway of recent years, but are not yet common. In tonnage plants there has been a definite trend toward the use of stationary-hearth furnaces of large capacity.

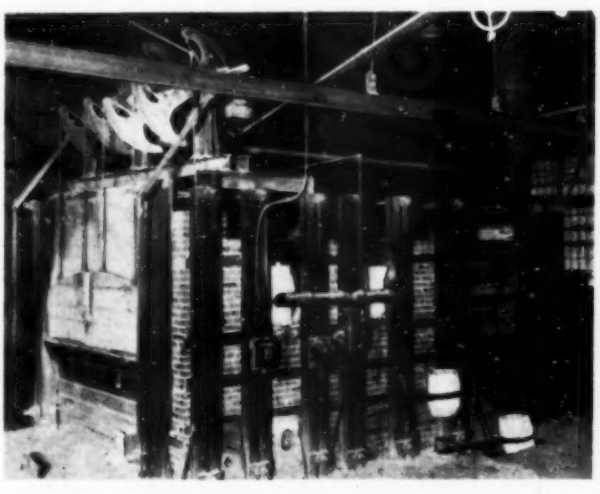


Fig. 1.—Tapping side of large stationary-hearth furnace, gas fired.

Such furnaces are favoured in American practice for melting 2 S, 3 S, and duralumin. Small lots may be melted in tilting-hearth or barrel-shaped open-flame tilting furnaces.

Broadly speaking, the choice of furnace to be employed in aluminium melting, whether in rolling-mill work or elsewhere, should be determined by (1) the type of material to be melted, (2) the tonnage to be handled, and (3) the most economical fuel available. Where operations are conducted on a small scale, the old-fashioned pit coke furnace, or the more modern gas- or oil-fired crucible furnace may be used. As a rule, however, these types are notoriously inefficient as to fuel. Open-flame furnaces of any type are likely to have much better thermal efficiency than crucible or iron-pot furnaces, although the oxidation losses with the former

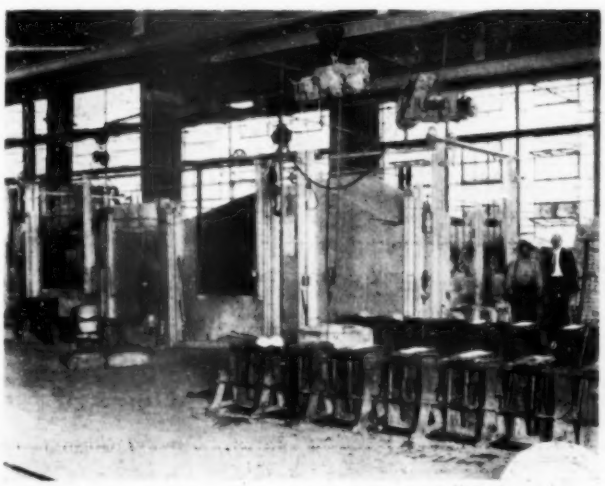


Fig. 2.—View of stationary-hearth furnace, fired by coal or coke.

may be considerably higher if not properly operated. In mills where 25,000 lb. to 100,000 lb. or more of metal are melted per day, large units are required, and accordingly the stationary-hearth furnace of large capacity is favoured. Where only 5,000 lb. to 10,000 lb. are melted per day, the writer recommends the tilting-hearth or barrel-shaped open-flame tilting furnace.

Sound engineering demands that the furnace capacity should be adjusted to the quantity to be melted, so that the units will be as large as possible up to a certain maximum. The operation of a battery of small units is distinctly uneconomical as compared with a large unit of equivalent capacity. Large furnaces are advantageous, irrespective of the type, as contrasted with small units, since the former provide faster melting, use less fuel per unit weight of metal liquified, are easier to charge, and have lower operating costs for labour. Moreover, the installation cost of a large unit is considerably less than that of a battery of small units having corresponding total capacity.

Any detailed discussion of aluminium melting would require a volume of itself. In the present article, it is the writer's object to discuss briefly the types of furnaces which are best adapted to melting in the rolling mill. These include the fuel-fired stationary and tilting-hearth furnaces, gas- and oil-fired barrel-shaped open-flame tilting furnaces,

4 R. J. Anderson, "Iron-pot Melting Practice for Aluminium Alloys," *Metal Ind.* (London), vol. 19, 1921, pp. 189–190; 246–247; 285–287; 360–362; and vol. 20, 1922, pp. 60–61; 309–316.

5 R. J. Anderson, "Aluminium Melting Practice," *The Foundry*, vol. 50, 1922, pp. 737–741; 792–797; 823–826; 866–870; 919–924.

6 R. J. Anderson, "Aluminium and Aluminium-alloy Melting Furnaces," *Trans. Amer. Foundrymen's Assoc.*, vol. 30, 1923, pp. 562–604 (see for extensive bibliography).

9 R. J. Anderson, "The Metallurgy of Aluminium and Aluminium Alloys." Henry Carey Baird and Co., New York, 1925, 913 pp. Chapters IX. and XIV.

17 R. J. Anderson, "Secondary Aluminium." The Sherwood Press, Inc., Cleveland In press; to appear January, 1931; Chapter X.

and hearth-type electric furnaces with metallic resisters as the heating elements. Reference will be had to recent tendencies and the future trend of practice. Information regarding crucible and pot furnaces may readily be had elsewhere. Owing to the confines of space, details of firing, burners, fuels, thermal efficiencies, furnace construction, refractories, and other important matters can be given only passing mention, if dealt with at all.

Stationary-hearth Furnace.

Hearth-type or reverberatory furnaces of various designs, fired by gas, oil, coal, and coke, have found considerable application for melting in the aluminium-rolling mill.

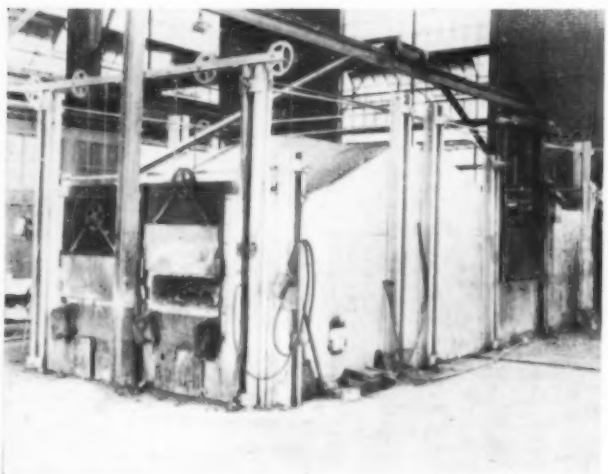


Fig. 3.—Firing end of stationary-hearth furnace.

Hearth-type furnaces may be classified as (1) stationary hearth, tapping type ; (2) stationary hearth, ladling type ; (3) stationary hearth, divided-chamber type (either tapping or ladling) ; and (4) tilting hearth. Among these the stationary-hearth furnaces, tapping type, particularly in the larger sizes, are most common in aluminium-rolling mills. The first stationary-hearth furnaces built for aluminium melting were of rather small size as compared with the units constructed of recent years. Thus, the early furnaces had capacities of up to about 6,000 lb. Later, furnaces were built to hold 12,000 lb., and then 20,000 lb., and others having capacities of 30,000 lb., 40,000 lb., and 50,000 lb., as well as larger, have now been put into operation in various branches of the aluminium industry. One company favours the use of stationary-hearth furnaces, tapping type, having capacities of 15,000 lb. to 16,000 lb., and 20,000 lb. to 22,000 lb. of aluminium. In the plant of another company, units holding about 35,000 lb. are considered desirable for tonnage melting in the production of rolling ingots. In passing, it may be pointed out that units of large capacity are best adapted to continuous melting.

The so-called reverberatory or stationary-hearth furnace, as used in aluminium practice, takes its name from the well-known copper reverberatory in which the flames from the combustion of fuel on a grate enter the hearth chamber over a bridge wall, striking the roof and being deflected, or reverberated, downwards toward the metal bath. In the ordinary gas or oil-fired aluminium reverberatory furnace combustion of the fuel from burners takes place in the melting chamber above the hearth. As a rule, the burners project the flames horizontally, thereby avoiding direct impingement on either the roof or metal. Heating is accomplished both by the combustion of fuel in the chamber and by radiation from the roof and side walls. Coal and coke-fired stationary-hearth furnaces for aluminium melting are built somewhat like copper reverberatories, but much shorter ; an aluminium reverberatory which is 50 ft. long overall is considered large. Owing to the method of firing, they are necessarily operated with rather high roof temperatures.

The usual type of stationary-hearth furnace employed in aluminium melting consists of a fire-brick shell, tied together with buckstays and rods, and often sided with steel plates. The hearth is hollow, and built of fire brick or other suitable refractory. Details of design vary considerably, depending on the method of firing, capacity, whether of the tapping or ladling type, and other factors. In furnaces fired by gas or oil, the burners may be placed in the side walls or in the end walls. Burner location is dependent in large part on the positions of the charging openings. Thus, in one design there is one main charging opening which consists of a large double door covering the full width of the end opposite the stack. In this furnace two opposed burners are situated in each side wall. One small charging hole for feeding pig is situated in each side wall. In other designs the main charging openings are placed in the side walls, and the firing is from burners situated in one of the end walls. Thus, a burner may be placed on either side of the stack, the flames being projected to the opposite end of the furnace, and the hot gases being drawn back over the metal or along the roof to the flue (so-called cross-firing). Or two or more burners may be placed in the end wall opposite the stack, the flames being projected toward the flue opening. In furnaces fired by coal or coke, the fuel is burned on a grate set in a fire-box at one end, the flames sweeping forward over a bridge wall and venting at the opposite end through a flue to the stack.

Roof design depends considerably on the method of firing. The roof is normally arched over from one side to the other. When burners are placed in the side walls, the cap may be built with no slope towards the flue—*i.e.*, it lies horizontal. With coal or coke-fired furnaces or with furnaces fired from burners in the end walls, the cap is normally sloped down from a high point over the melting chamber to a low point at the flue, so as to deflect the flames and hot gases from combustion down upon the hearth. When solid fuel is burned the use of super-refractory bricks in the roof and bridge wall is indicated.

In the tapping type of stationary-hearth furnace, the hearth is sloped to a low point at a wall (either side or end)

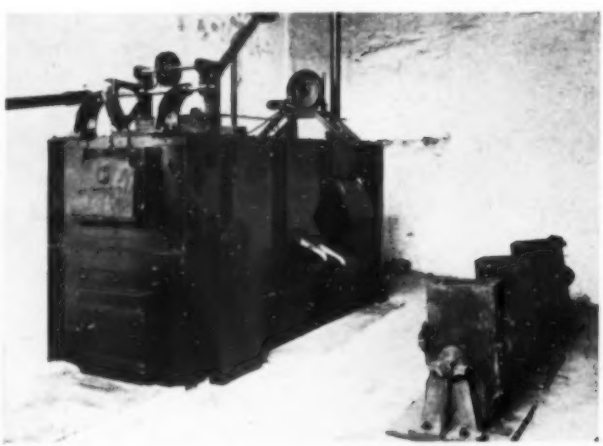


Fig. 4.—Stationary-hearth furnace (The Dsenicke Furnace Co.).

where a tap-hole is situated. In some designs two adjacent tap-holes are placed in the wall, one slightly higher than the other. Metal for pouring is taken out through the higher tap-hole, the lower one connecting to a basin or sump in which foreign matter accumulates. In batch operation, metal is removed and poured into ingots until the level of the higher tap-hole is reached. Then the remaining metal is drained from the lower tap-hole, poured into pigs, and subsequently reworked for the removal of non-metallic matter or the dilution of impurities. The tap-hole is closed with a suitable plug ball made of flour dough

and asbestos, or dough and clay. In tapping, the dough ball is knocked out, whereupon metal is free to flow down the runner into a crucible or ladle. When sufficient metal has been removed, the flow is stopped by plugging with a fresh dough ball. A tap-hole and runner may be combined as an integral casting made of grey cast iron. In the ladling type of hearth furnace the metal is removed by dipping with large ladles through door openings suitably positioned

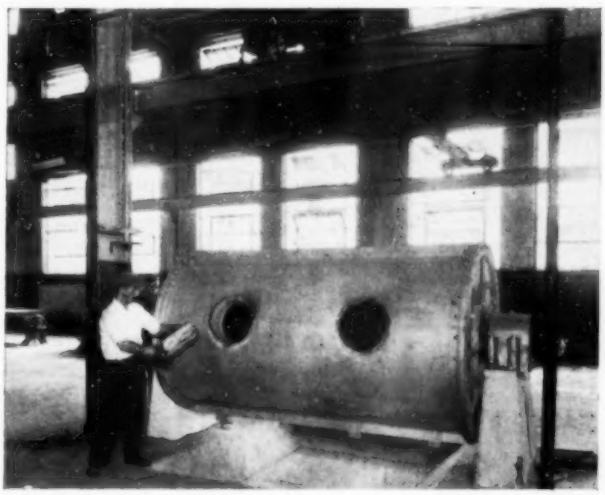


Fig. 5.—Oil-fired cylindrical tilting furnace.

in the walls. In some designs the metal is scooped up from a well or basin built integral with the furnace, and connected at the bottom to the hearth proper by means of an arched passage way. The construction of the ladling-type stationary-hearth furnace may be practically the same as that of the tapping type, aside from the shape of the hearth and provision for removal of metal. Stationary-hearth furnaces of the divided-chamber type have been used but little in rolling-mill melting.

Stationary-hearth furnaces may be built in any desired capacity over a wide range of sizes, from, say, 2,000 lb. to 100,000 lb. While large and continuous production is indicated for the effective utilisation of furnaces having capacities in excess of 15,000 lb. to 20,000 lb., the smaller sizes may be used to advantage where the output is limited or as auxiliaries in tonnage plants. As a rule, the tapping furnace is to be preferred to the ladling type. Constructional details of stationary-hearth furnaces of various sizes have been given by the writer[15] and associates[10 12] in previously published papers. From the point of view of first cost of installation, maintenance and depreciation, and labour and fuel costs, the stationary-hearth furnace, if correctly designed and operated, gives the best results in rolling-mill melting of any furnace when tonnage is to be handled. The chief advantages of this type of furnace include low first cost of installation per unit of capacity, as compared with other furnaces, rapidity of melting, and good fuel efficiency. Efficiencies in excess of 25% have been obtained in regular practice with furnaces ranging from 2,000 lb. to 40,000 lb. capacity. These furnaces are also easy to charge and operate.

Fig. 1 shows the tapping side of a gas-fired stationary-hearth furnace of about 35,000 lb. capacity. The large double charging door at one end of the furnace may be seen at the left. A small charging door is situated over the tap-hole, which may be noticed at the right, and a medium-size charging door is situated directly opposite in the other side wall. The furnace is fired by two opposed burners in each side wall, air for combustion being provided by small blowers. Fig. 2 shows a general view of a stationary-hearth furnace of the tapping type, having capacity of about 33,000 lb., fired by solid fuel. The firing end may be noticed at the right. The tapping spout is situated between the two charging doors in the side wall. Another charging door is in the other side wall opposite the tap-hole. A portion of a mould line-up is seen in the foreground. The slope of the roof may be noted. In Fig. 3 is seen a view of a similar furnace, showing the firing end and the side wall opposite the wall containing the tap-hole. Fig. 4 shows a small stationary-hearth furnace with two tap-holes, used for the purpose described above. The output is given as about 225 lb. of metal per hour.

Tilting-hearth Furnaces.

Tilting-hearth furnaces of rather small capacity have found application in melting prior to pouring rolling ingots. In American practice such furnaces are favoured as auxiliaries in large plants for melting small lots of alloys. These furnaces have been fired by gas, oil, and solid fuel. So far, large-size tilting furnaces of the hearth type have not been favoured for rolling-mill melting, although they present a number of decided advantages. The chief disadvantage is high first cost, much of this cost being absorbed in the mounting and tilting mechanism, the cost for such mechanism rising rapidly with increasing capacity of furnace. The construction of tilting-hearth furnaces, as regards hearth, walls, roof, ironing, and firing, may be similar to that of the stationary type. Analogy is had in the tilting open-hearth furnace used in steel practice. The furnace superstructure may be supported on trunnions or on curved rockers and wheels, the tilting being accomplished by means of geared mechanism. Difficulties of construction and costs are increased when tilting-hearth furnaces are designed for firing with solid fuel. Some furnace men feel that the tilting-hearth furnace is a satisfactory and economical proposition for aluminium melting up to a capacity of about 5,000 lb., but that for larger capacities cost of construction is too high to warrant its use in place of the stationary-hearth furnace, despite the advantages of the former.

One serious disadvantage of the stationary-hearth tapping furnace is inherent in the method of removing

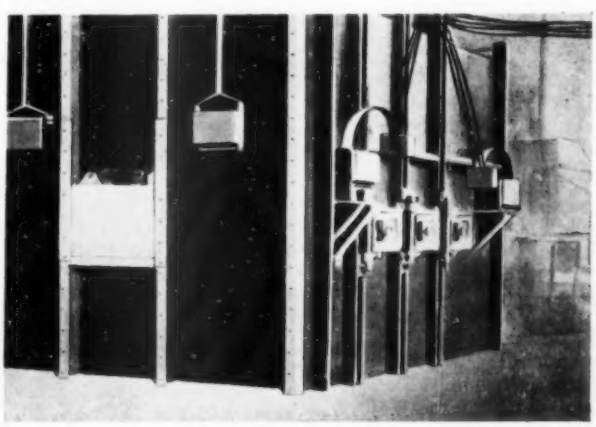


Fig. 6.—Baily stationary-hearth electric furnace.

metal. Every time the tap-hole is closed and the metal flow stopped, there is more or less gassing of the metal, caused by the steam evolved in the drying of the damp plug ball. This is, of course, entirely eliminated in the tilting furnace. Also, there may be occasional troubles in operating stationary-hearth furnaces, due to frozen tap-holes, and also explosions in plugging. Moreover, the control of metal flow in tapping becomes impossible with a worn tap-hole and a high head of metal in the furnace. Tapping-type furnaces are more dangerous to operate as

15 R. J. Anderson, "Kleiner Flammofen zum Schmelzen von Aluminium und Aluminium-legierungen," *Metallwirt*, vol. 9, 1930, pp. 899–901.

10 R. J. Anderson and G. E. Hughes, "Melting of Aluminium with Gas for Production of Rolling Ingots," *Industrial Gas*, vol. 7, 1929, pp. 7–8, 12, 30.

12 R. J. Anderson, G. E. Hughes, and M. B. Anderson, "An Open-flame Stationary Hearth-type Furnace for Melting Aluminium and Its Alloys," *Trans. Amer. Foundrymen's Assoc.*, vol. 37, 1929, pp. 153–162.

regards the possibility of men being burned by spattering metal. Although the stationary-hearth furnace is most generally used in rolling-mill melting, particularly where the production is large, the writer believes that the tilting-hearth furnace will come into greater favour in the future, despite its higher initial cost. Tilting-hearth furnaces for melting aluminium and other non-ferrous metals are built as standard equipment in relatively small sizes by various manufacturers.

Open-Flame Cylindrical Tilting Furnaces.

Open-flame tilting furnaces of several designs have found some application for melting in the rolling mill, both in the United States and abroad. The design usually preferred is the cylindrically-shaped, or so-called barrel, furnace. Open-flame tilting furnaces are fired by oil or gas, and combustion of the fuel takes place in the melting chamber above the metal. The cylindrical tilting furnace consists of a steel shell of the desired size, lined with refractory brick or shapes, and mounted on trunnions or otherwise. Suitable mechanism is provided for tilting by hand or by electric-motor drive. Capacities range up to about 10,000 lb. of aluminium, and for rolling-mill melting furnaces holding about 5,000 lb. or 7,500 lb. of metal have been used mostly. Firing is by burners through the trunnions or side walls. Burners should not be placed so that they blast down upon the metal.

Pear-shaped, upright tilting furnaces—*e.g.*, the Hawley - Schwartz type—are not ordinarily regarded as suitable for aluminium melting. A cylindrically-shaped rotating-and-tilting furnace, developed especially for melting in enamelling practice, was used at one time for melting aluminium in certain small rolling mills.[8] This type of furnace is rotated on its long axis, and is tilted for pouring on a short axis. One burner is placed so as to project flame through a hole at one end, and the products of combustion are discharged through the pouring spout at the other end. Increased thermal efficiency is claimed for this furnace by reason of absorption of heat from the entire surface of the lining due to the rotation.

Aside from hearth furnaces, either stationary or tilting, the only other type of fuel-fired furnace well adapted to melting prior to pouring rolling ingots is the cylindrical tilting furnace. One or two such furnaces of 5,000 lb. to 10,000 lb. capacity may serve as the principal melting units in a small plant, or may be used as auxiliaries in a large plant. Fig. 5 shows the charging side of an oil-fired cylindrical tilting furnace of 6,000 lb. capacity. The charging openings may be made sufficiently wide so as to receive fairly large pieces of metal. In the furnace shown, the pouring spout is situated on the opposite side.

Firing is through burners inserted in the opposed trunnions. Details of the construction and operation of this furnace have been given elsewhere by the writer.[11] [14] As is the case with other open-flame furnaces, this type has the advantage of good fuel efficiency, and it has the additional advantage of the tilting feature.

Electric Furnaces.

About 1918 a number of electrically-heated furnaces were installed in different plants for various aluminium-melting operations, but in several instances their use was subsequently discontinued, mainly on account of high costs for power. So far, electric furnaces of any type have been used but little for aluminium melting, either in rolling mills or elsewhere, but increasing interest has been taken in these furnaces of recent years. In melting aluminium and its alloys for casting into rolling ingots, the writer believes that electric furnaces offer no advantages worth paying a stiff premium for. Where rolling mills are situated so as to have access to cheap power, the situation is quite different, and electric furnaces may then be employed to advantage.

Indirect-arc and granular-resister furnaces have been advocated for aluminium melting because they operate with reducing (carbon monoxide) atmospheres, and therefore (*sic*) will yield lower oxidation losses. However, large-scale melting tests with these furnaces have not shown any lower dross losses than when melting in fuel-fired furnaces. With electric-power costs being much higher than corresponding fuel costs, except at isolated places and under special conditions, the electric furnace must save enough metal by preventing oxidation to pay the difference between the cost of power and fuel—*i.e.*, if no account is taken of quality of metal, ease of control, labour costs, and other factors. The first cost of an electric furnace, including lines and switching, is very much higher than that of a fuel-fired furnace. There are, of course, certain inherently desirable features in electric melting, but it has not been demonstrated to the writer's satisfaction that these are worth the extra cost in the case of rolling-mill melting. On the other hand, in holding aluminium alloys at definite temperatures in permanent mould practice, the situation is different.

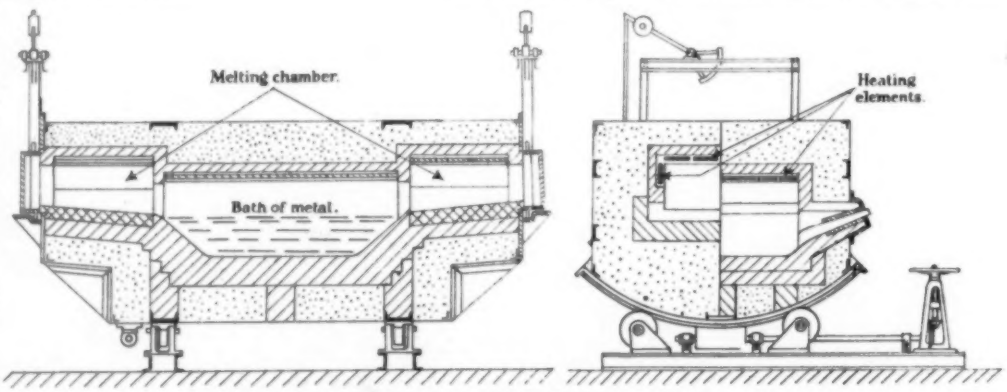


Fig. 7.—Russ electric melting furnace (Bellin).

The Baily granular-resister furnace[2] was probably the first type of electric equipment used for large-scale aluminium melting. A 500-k.w. furnace was installed about 1918 in the Massena, N.Y., plant of the Aluminium Co. of America. This was of the stationary-hearth tapping type, and it had a capacity of about 7,500 lb. Fig. 6 shows a view of this furnace. Baily furnaces are no longer built. The tilting-hearth, metallic-resister furnace of the Russ type, built by the Industrie Elektroofen, G.m.b.H., Cologne, Germany, is a satisfactory design for use in rolling-mill melting. Russ furnaces have been described by Bellin[13] and by Russ.[16] These furnaces are built in capacities of up to about 4,500 lb. as standard equipment. Cross-sections of the Russ tilting-hearth furnace are shown in Fig. 7. Electrically-heated furnaces of the metallic-resister type are employed exclusively for melting at the rolling mill of the Vereinigte Leichtmetall-Werk G.m.b.H., Bonn, Germany.

8 J. A. Lange, "Melting Aluminium for Rolling into Sheet," *Trans. Amer. Foundrymen's Assoc.*, vol. 30, 1923, pp. 551–559.

11 R. J. Anderson, "Ein zylindrischer Kippflammofen zum Schmelzen von Aluminium-legierungen," *Metallwirt*, vol. 8, 1929, pp. 747–748.

14 R. J. Anderson, "An Open-flame Tilting Furnace for Aluminium Melting," *Industrial Gas*, vol. 9, 1930, pp. 7–9.

2 D. D. Miller, "The Remelting of Aluminium Pig in the Electric Furnace," *Chem. Met. Eng.*, vol. 19, 1918, pp. 251–254.

13 A. Bellin, "La Fusion de l'Aluminium au Four Electrique," *Jour. Four. Elec.*, vol. 38, 1929, pp. 377–380: 416–419.

16 E. F. Russ, "Das elektrische Schmelzen von Aluminium," *Zeit. Metallkunde*, vol. 22, 1930, pp. 273–276.

The New Alloys and——— Machine Tool Design

By Francis W. Shaw, M.I.P.E.

The development of alloys for cutting tools is surveyed, and the function of elements in these alloys is discussed in the light of present progress.

HOW much the productive world owes to Robert Forrester Mushet is not easy to divine. What machine tools would have been to-day but for Mushet's accidental discovery of the air-hardening properties of an experimental bar of steel, too, is hard to realise. The new element from which this bar derived its peculiar properties proved to be tungsten, or, rather, this metal combined with ferrous oxide in the mineral wolfram ($FeWO_4$) along with a larger manganese content than had been used before. That speedier cutting of metals had now become possible was evident; yet for some inscrutable reason the new steel did not meet with the reception that nowadays would be expected of improvements of even less moment.

Of what is now known as high-speed steel there is some doubt as to whom should be accredited the discovery, if discovery there really was in a mere grouping of existent elements with a view to determining individual or collective effect. But it is reasonably certain that to F. W. Taylor must be awarded the credit for the discovery of the process by which high-speed steel gets its "red-hardness," the property which elevated the possibilities for rapid cutting to undreamt-of heights.

"Taylor-White" Steel.

It is noteworthy that Taylor did not attribute the higher speed capability of the steel that came to be known as "Taylor-White" high-speed steel, to any new element, nor to different proportions of the elements, for even with a tungsten content of but 1%, and chromium as low as 0·5, heating the steel almost to fusing—the Taylor treatment,—imparted to the steel "an entirely new property, 'red-hardness,' and it is this property which enables these tools to run at high cutting speeds." (Taylor's own words). The original mushet, treated in the Taylor fashion, would have benefited likewise. Unfortunately, users were warned that to heat the steel beyond "cherry-red" would be disastrous.

The next step towards higher cutting speeds was to increase the tungsten and chromium content, but despite continued improvements the simpler carbon-steel tools hung on with tenacity—for very good reasons. Not only were the new steels difficult to forge, but the bar was liable to fracture lengthwise, either in the process or as it cooled. And, when finished, tools would break under stresses that carbon-steel tools would easily resist. So much expensive steel was lost in these "incidents and accidents" of preparation and use that to many the steels proved, if not a source of pecuniary loss, at least but dubiously profitable. Yet users who contemporaneously put their heat-treatment houses in good order, and saw to it that the tools were employed in machines capable of utilising them to advantage, found in the steel all that its makers claimed it to possess.

Such was the position up to about 1906, when it was discovered that the element vanadium, even in the smallest quantities, stiffened the steel and increased its durability. A cutting speed of about 100 ft. a minute on steels of medium hardness was now possible, against about 50 ft. with steels of the original Taylor-White type, 30 ft. with mushet, and 15 ft. with the finest carbon steel. At the same time, the influence of other rare or semi-rare elements was under investigation, their effect in appropriate combinations being, as shall be described later, to increase the possible cutting speed from about 100 ft. to 150 ft. under like conditions. Moreover, the steels were more reliable, and were more durable at moderate speeds. Of the new elements, cobalt, displacing iron to the extent of 3 to 5%, seems to have had the greatest effect. And such is now the position of what may be termed the super-high-speed steels of to-day.

Stellite.

About ten years after the advent of the original Taylor-White steel, came a non-ferrous metal, or, rather, an alloy in which iron, when present, existed only as an impurity. This alloy, termed "Stellite," was invented or discovered by E. Haynes, of Kolomo, Indiana. Whilst it possessed to a marked degree the quality of red-hardness, enabling it to cut at speeds sufficient to give it a red heat, it suffered frequently from the faults to which many cast metals are addicted—the fault of being brittle and the fault of being locally porous. Pores at the cutting edges were fatal to good performances either in speed or finish of surface. From a good piece of the metal, however, results far beyond those possible to the finest high-speed steel were obtainable, speeds of 300 ft. a minute on medium steel not being out of the way. Despite these faults, there is good reason to suppose that in it high-speed steels would have found a formidable competitor, had the price at which it was then sold been more favourable. It cost about £1 a pound against 4s. for high-speed steel.

In composition it varied considerably more than the three grades in which it was nominally sold would suggest ought to have been permitted. Whilst it was generally stated that the alloy was of chromium 25%, cobalt 65%, molybdenum 10%, in some samples analysed, the molybdenum appears to have been displaced by tungsten, and in others were found carbon, silicon, manganese, and iron in quantities such as to raise a doubt as to whether their presence was merely accidental or purposeful.

Stellite, improved, is a material which, at the moment, ranks high as a metal remover, particularly where the cuts and feeds are moderate. It is one of the most durable alloys known, tools made therefrom often lasting for a week or more between grindings. Supplied by the Deloro Smelting and Refining Co., Ltd., it is obtainable applied to tipped tools of all standard sections and in rectangular pieces, or in pieces cast to special form.

Our conclusion, after a careful study of facts as they are, and not as interested people would like them to be, is that whilst Stellite plays a useful part in the economy of machining, it cannot arrogate to itself an era such as it might be claimed high-speed steel enjoyed and still holds. For it can be said with conviction that the total demand for Stellite and similar alloys does not nearly equal that for high-speed steel.

Widia.

Whether our conclusion holds good for the present forms of tungsten-carbide—we say "present," for the alloy has long been known as a material approaching the diamond in hardness,—the future alone can tell. However this may be, it is certain that, the engineering world over, Widia, the product of Friedrich Krupp, of Essen, is commanding vast attention and an ever-growing demand, though only introduced in 1926.

The porous structure to which cast metals are given, is obviated in this alloy in a very ingenious manner, a manner, too, which imparts to the material its intense hardness. Its ingredients, separately pulverised in a ball-mill to a

grain size of 0·0001 in., are carefully sifted and then mixed in the desired proportions. After being hydraulically pressed in moulds to the required shape, under a temperature of 400° to 500° C., the "mouldings" are crystallised or sintered, as is the technical expression, in a stream of hydrogen, in an electric furnace, at a temperature of 1,400 to 1,500° C. Cooled—carefully, to prevent distortion or the formation of cracks,—the mouldings are nearly diamond-hard—so hard, indeed, that only by grinding can their shape be altered.

Owing to the presence of cobalt as a sort of matrix for the tungsten carbide, the alloy is far stronger than would be tungsten carbide by itself. Unhappily, with any addition to the cobalt content beyond 5%, at which the material is at its hardest, but with its least tenacity, the hardness decreases. The addition of cobalt to the extent of 20% results in a material too soft for cutting tools, but with 15% cobalt the hardness falls short of that of the diamond by but 5%—so it is claimed without indication of the measure of hardness. Even with this high cobalt content, Widia, it is freely admitted, has a tenacity far short of that of high-speed steel. Though its suppliers in this country, A. C. Wickman, Ltd., hold a large stock of cutting tools of all the usual and some unusual shapes, and standard rectangular pieces suitable for small cutters, its use is severely restricted, particularly among those to whom a lump initial capital outlay (the tools are comparatively high-priced) counts more than small weekly wage-savings.

As with Stellite, our conclusion is that Widia is not likely to have an era all to itself until engineers as a whole are financially unembarrassed, and until it has attained a tenacity near to that of modern high-speed steel.

Widia is capable of cutting speeds of from 120 ft. to 200 ft. a minute for roughing cuts, and of from 350 ft. to 600 ft. for finishing cuts on mild-steel bars or forgings—a considerable advance on the speeds for any of the materials of which we have spoken. Compare 600 with the 30 of which the finest carbon-steel tools are capable!

Both Stellite and Widia can profitably be employed on soft and abrasive materials, such as rubber, vulcanite, bakelite, porcelain, and slate; and on chilled iron and hard manganese steel they are particularly effective.

How Elements Function in Alloys.

Whilst it is a mistake to judge of a steel's cutting qualities entirely by analysis, it is logical to suppose that, other things being equal, cutting capacity is a function of contents. Methods of producing the steel, the amount of care bestowed in mixing and melting, the casting temperature, and many other details familiar to the steelmaker, influence the quality to a greater extent than is realised by those firms, or their unscientific purchasing agents, whose sole criteria of a profitable steel are its analysis and price. Such firms can always find a multitude of selling agents willing to oblige.

To those firms whose habit it is to purchase solely from firms of repute, a brief study of the influence of the divers elements in the alloys may be helpful, for the user is generally the best judge of his own conditions.

Carbon.—In the original mushet, the carbon content was far higher than it is in modern high-speed steels—2·5%, against an average of about 0·8%. The function of carbon is too complex for complete consideration here, but it can safely be said to act as a hardener, whatever be the other contents. But carbon also embrittles, and therefore the greater the carbon content, the more friable are the cutting edges of tools likely to be. For general use steel of about 0·8 carbon content seems most suitable; where the tools are subject to shock, as in planing and other reciprocating machines, or in roughing uneven forgings and castings, the carbon percentage should not exceed 0·65; for light finishing cuts the percentage can be as high as 1·5 where good finish is imperative, and 1·2 where surfaces are finished, after machining, by grinding. Carbon, may we add, in part combines with some of the other elements—tungsten and chromium in particular,—yielding carbides of these elements.

Tungsten.—As has been stated, it is to tungsten that high-speed steels owe their high-speed qualities, and their power to cut while red-hot and to retain their hardness upon cooling. Like carbon, it is a hardener; but, unlike carbon, it does not embrittle. It improves the steel's tenacity to a marked degree, offsetting the weakening effect of carbon. It raises the fuse-point of the steel, increasing melting difficulties.

Vanadium.—Vanadium, again, is a hardener, increasing the red-hardness. Having a strong affinity for oxygen, it is thought to act as a purifier. A small quantity greatly increases the tenacity of tungsten steels, but the advantage of this is discounted by additions aimed at improving the red-hardness. Where tools are intended for finishing cuts only, it is doubtful whether more than 0·3% is useful.

Chromium.—This, too, improves red-hardness and toughens the steel, increasing the tool's resistivity to shocks and abrasion. Modern steels contain from 3·5 to 5%, though as much as 10% has been used, probably on account of its low price compared with that of some of the other elements which impart similar qualities.

Molybdenum.—Whilst possessing red-hardening qualities to a far greater extent than tungsten, its introduction increases the tendency of the steel to crack on being quenched. Further, it is not so stable as some of the other elements, particularly after several rehardenings. For this reason, its use has been discontinued generally.

Manganese.—Present in high-speed steel to the extent of about 2%, manganese increases tenacity, strength, and workability. With greater percentages the steel is liable to fracture.

Uranium.—This element is a powerful cleansing agent, particularly of oxygen and nitrogen and their compounds. Published analyses do not disclose its use in any of the modern steels. According to the July, 1930, issue of the *Journal of the Institute of Production Engineers*, Messrs. Alfred Herbert, Ltd., appear to have found uranium valuable in steels containing cobalt. Probably its call for extreme care in mixing and manipulating at the forge has militated against its more frequent use, for it is undoubtedly a means whereby steel may be strengthened and its resistivity to shocks increased.

Cobalt.—Cobalt enters into many modern steels in percentages of from 3 to 5. It would appear that this element, though to it is attributed a tendency to induce a softening of the cutting edges with time and use, adds to a steel's durability and enables speeds to be increased on the harder materials.

Nickel.—In combination with about 0·8% tungsten, 0·25% vanadium, 3% chromium, and 0·3% carbon, nickel to the extent of about 2% is claimed to meet the difficult case of hot stamping dies, which must retain their hardness at or near forging temperatures, and must have shock- and wear-resisting qualities.

Titanium has been tried, but does not appear to have any superiority over lower-priced elements.

Zirconium.—The same can be said of this element.

Silicon, sulphur, and phosphorus are always present in small quantities, generally less than 0·04%.

Of the above elements, those present in Stellite and Widia probably function as in high-speed steels. It would, however, seem that Stellite owes its extreme hardness as much to the absence of the element iron as to the high percentages of the other elements, and Widia as much to its fine crystalline structure as to its elements, though, of course, it is upon these its structure depends.

The Trend and the Future.

A comparison, which can only be rough, of the proportions of certain elements in current cutting materials may indicate the trend and what the future has in store. In the following table the approximate percentages of the

(*Continued on page* 61.)

Bimetal—Its Function and Application*

By W. J. P. Rohn, Dr Phil.Nat.

Deflection curves of different bimetal combinations—Instruments for testing bimetals—Technical aspects of the manufacture and application of bimetals.

IN the previous article, the differences in the specific properties of two metals were considered in connection with bimetals. It was assumed in the foregoing discussion that the geometrical shape and size were identical in each case. It will, however, readily be appreciated that the amount of curvature, and the possibility of utilising this with advantage, will depend largely upon its dimensions as well as its component metals. It will, therefore, not be amiss to give some consideration to this aspect of the subject.

The absolute differences in length between the components of any particular bimetal combination, which arise from temperature changes, depend solely upon the properties of the two components. The amount of bending of a bimetal strip will increase as the strip becomes thinner,

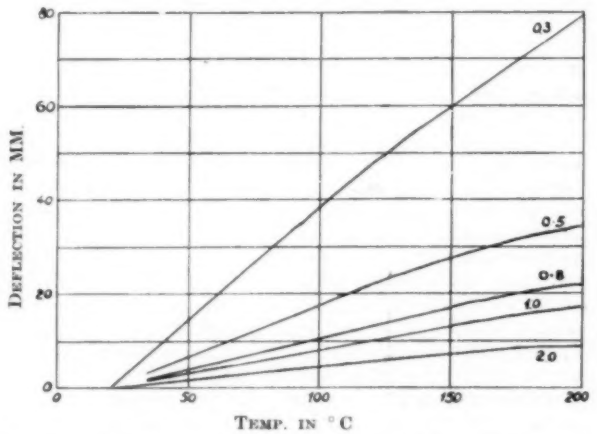


Fig. 7a.—Deflection of a Bimetal of Various Strip Thicknesses in relation to Temperature. (Test Strips are Invar-Nickel 100 mm. long × 10 mm. wide).

since with thin sections the neutral layers are brought very close together.

In Figs. 7A and 7B the deflection curves of the same bimetal combination have thicknesses varying from 2·0—0·3 mm. In the lower part of the figure the relationship between the curvature and the thicknesses of this bimetal combination is shown for a constant temperature of 150° C. It is clear that in order to obtain the greatest effect, the thickness of a bimetal strip must be as small as possible, but it must also be remembered that the force which the free end of a bimetal strip is able to exert is proportional to the third power of the thickness of the strip. The force at the end of the strip consequently decreases more rapidly than the curvature increases. Since it is not always possible to keep the width of the strip inversely proportional to the third power of the thickness, a limit is very soon reached at which the force exerted at the free end of the bimetal is no longer great enough to operate a mechanism or open and close a contact with sufficient certainty. Advantage, however, can be taken of the following arrangement. A large number of bimetal strips are piled up so as to form a pack. One end of this is tightly clamped, while at the other end each strip is left to move freely.

* *Continued from the November issue.*

Moreover, it is evident that the sensitiveness to shock and other mechanical contingencies, becomes great with reduced strip thicknesses and increased strip length, so causing the operation of mechanism or contacts to become uncertain. It is generally more advantageous to employ a bimetal with an amplitude of only one-tenth of a millimetre in which an accuracy of 97—98% is obtainable, rather than one having a distance of travel of several millimetres, but which is subject to an error of 15—20%. In most cases it is safer to use shorter, thicker, and perhaps wider bimetal strips, which thereby have the advantage of complete accuracy over a small amplitude. When a bimetal has directly to open or close an electric contact, and the current in use is too small to have the properties of an arc between the open contact points, a travel of a fraction of

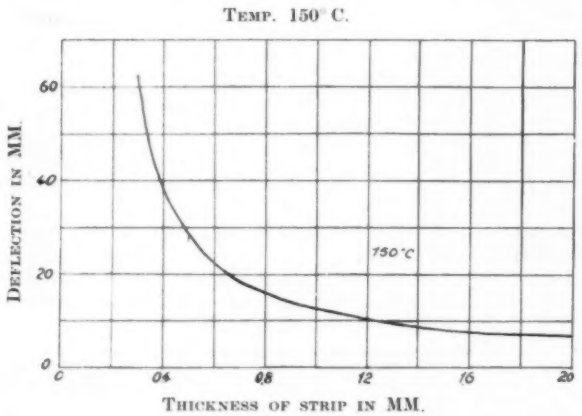


Fig. 7b.—Deflection of a Bimetal of Various Strip Thicknesses in relation to Temperature. (Test Strips are Invar-Nickel 100 mm. long × 10 mm. wide).

1/100th of a millimetre is sufficient to make or break a circuit with complete safety. It can sometimes be arranged that only a fraction of the current is broken by the bimetal so operating the regulation, but a certain residual current is allowed to flow continuously. In other cases a relay must be used.

Since, on heating, a bimetal bends in the shape of an arc, the deflection of the free end of a bimetal strip is proportional to the square of the length, so long as the deflection of the free end is relatively small in comparison with the length of the strip. The force that the free end of the bimetal strip is able to exert, is in its turn inversely proportional to the cube of the length of the strip for any definite thickness. With a strip of constant length it is directly proportional to the cube of the thickness. If the length of a bimetal strip is increased n times, the width must be increased by n^3 in order to get the same force exerted at the free end for making or breaking a contact. If the length l is increased n times, and at the same time the thickness is increased n times, the width remaining constant, then the deflection will be $n^2 : n - n$ times as great. The force by lengthening n times decreases in the proportion of $l : n^3$, and by increasing the thickness n times increases in the proportion of $l : n^3$. In effect, this

means that the force at the free end of a bimetal strip remains constant if the length is increased in the same proportion as the thickness, but the resulting deflection is n times as great.

If it is required, therefore, to increase the sensitivity of a bimetal strip—*i.e.*, the amount of deflection—by increasing its length or decreasing its thickness, but at the same time retaining enough power to operate or break a contact, the thickness must be proportionally increased or the width increased proportionally to the third power.

A bimetal strip bends not only in the direction of its length, but also in the direction of its width, so that in its bent position its shape is not the section of a cylinder, but that of a sphere. It is generally held that this cross-bending interferes with the deflection in the direction of the length, and therefore that a wide bimetal strip bends less than a narrow one.

To substantiate this or otherwise, experiments were carried out with the following results :—

TABLE II.

DEFLECTION OF BIMETAL STRIPS OF DIFFERENT WIDTHS AT A CONSTANT TEMPERATURE (100° C.).

Width of strip in mm.	5	10	20	30	40
Deflection at 100° in mm. ..	11·95	12·0	12·05	12·0	22·05

Table II. gives the deflection of the free end of a bimetal strip of Invar-Constantan, 100 mm. long and 0·6 mm. thick, for different widths ranging from 5—40 mm. Although the width of the strip varies in the proportion of from 1 to 8, and at its greatest the width is 40% of its length, still, the deflection measured at the free end differs only by a fraction of 1%. There is, then, in fact, no objection to increasing the width of a bimetal strip, and it is possible to use, without detriment to the sensitivity, much wider strips than has hitherto been thought possible.

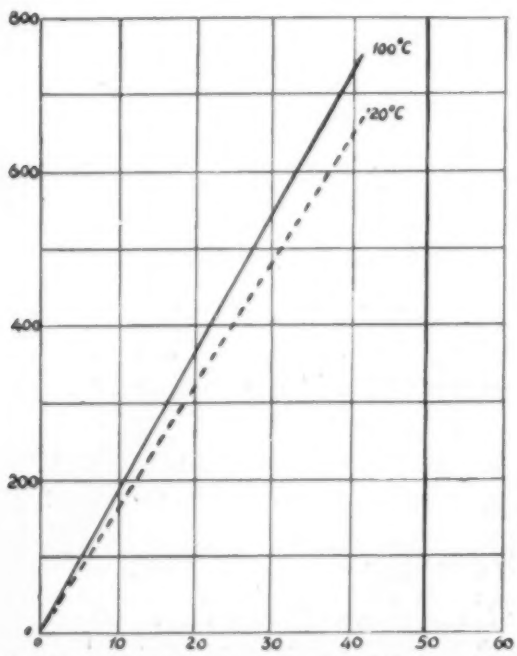


Fig. 8.—Force required to give a Constant Deflection to Bimetal Strips of Various Widths.

On the other hand, it might be supposed that a strip curved in two directions must be more rigid than one bending only in one direction, and therefore, at the end of a bimetal strip bending in two directions there should exist a relatively greater force, but this supposition is shown experimentally to have no foundation. In Fig. 8 different strip widths are shown as abscissa and as ordinates, the loads in grammes which will cause a deflection of 12 mm. in an Invar-Constantan strip 0·6 mm. thick and 100 mm. long. The continuous line is for a temperature of 100° C., and the dotted line is for room temperature. It will readily be observed that the force to deflect the strips through 12 mm. for widths ranging from 5—40 mm., lie exactly on straight lines, and that these lines pass exactly through the origin.

It is naturally possible to arrive at these phenomena and characteristics of a bimetal mathematically, but the derived formulæ are rather complicated. The angle subtended at the centre of the arc formed by the bimetal appears in these formulæ first as the argument of a trigonometrical function, and then as the function of an arc. For reasons previously explained, such calculations

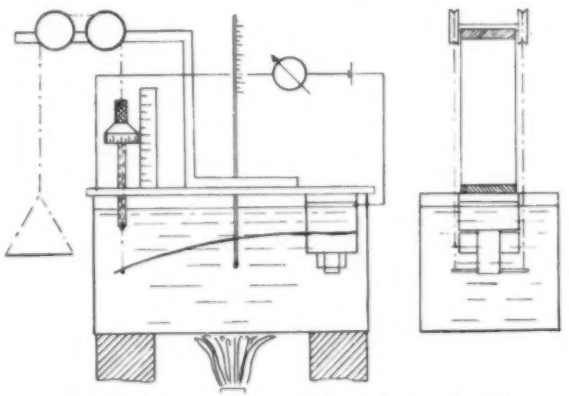


Fig. 9.—Laboratory Apparatus for Testing Bimetals.

cannot give accurate results. In general, it is better to calculate approximately the deflection and force, and then to test the results deduced, experimentally, in order to check the dimensions chosen.

The following are some methods of testing bimetals. Fig. 9 shows an apparatus suitable for laboratory research work. A bimetal strip fixed at one end is immersed in an oil bath which can be heated. The deflection of the free end is measured by means of a micrometer screw, the precise instant when the bimetal makes contact with the screw, being recorded by an electrical device. Under the bimetal strip, a stirrup-like crosspiece is placed, which is connected with a weighing device over two freely moving pulleys. The weights in the pan are a measure of the force that is necessary to obtain a certain deflection, the magnitude of the deflection being adjusted by the micrometer screw. Oil baths may be used only up to 300° C., or at the most 350° C. For higher temperatures, it is better to cover each side of the bimetal with a thin sheet of mica and use a coil of resistance wire for heating. The temperature is measured by means of a thermocouple inserted between the bimetal and the mica. This arrangement is shown in Fig. 10.

For testing on a large scale, a more convenient apparatus is one in which the strip, say 70 mm. long and 10 mm. wide, is fixed at one end and heated by means of an electric current passing through it. Here, instead of recording the temperature, the current passing through the strip is measured. The movement of the free end of the bimetal strip is magnified by means of a pointer. In this test it is usual to specify that for a certain current there must be a minimum deflection of the pointer. Very often the same test is repeated with a definite weight attached to the free end of the bimetal, and from experience it is found that a certain load and current strength should produce a definite minimum movement of the pointer. Convenient apparatus for doing this is shown in Fig. 11.

Finally, there are certain technical points in the manufacture and working of bimetal which deserve attention. In the first place, a perfect joint between the two components is of primary and paramount importance, and in the best modern practice only such alloys as lend themselves readily to perfect welding with other metals are

used. Since the accuracy of an instrument utilising a bimetal depends principally on the elastic properties of the combination, it is essential to use the material hardened by cold rolling and carefully heat-treated to obtain the highest possible tensile strength and elasticity. This makes it necessary, of course, to avoid sharp right-angled bends in the finished materials, since fractures are liable to occur

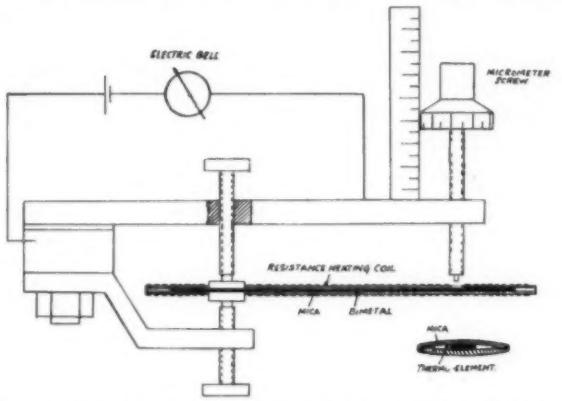


Fig. 10.—Laboratory Apparatus for Testing Bimetals at High Temperatures.

at these points. The radius of the bend should be at least five to eight times the thickness of the strip. In working bimetal, care must be taken not to destroy its elastic properties by overheating, therefore hard soldering must not be practised, and even in soft soldering every precaution must be taken not to overstep the softening or annealing temperature of either component. It is generally best to make the joint by clamping, screwing, or riveting. Care must also be exercised to avoid any warping which

HEATING CURRENT CONNECTIONS.

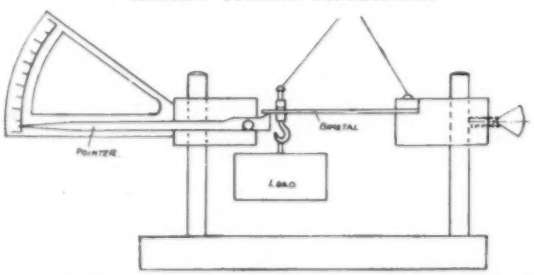


Fig. 11.—Apparatus for Testing Bimetals on a large scale. This Apparatus has been recommended to the author by a user of Bimetal.

will give rise to the "click effect." This can best be prevented by clamping the bimetal strip between two flat boards of sufficient thickness. Again, after the last operations are performed on the bimetal—these usually include riveting, bending, etc., and are done by the user—it is necessary to relieve any internal strains which may exist below working temperature, and which might injure the exact reproduction of the zero point. This ageing operation is best done by slowly heating the bimetal after the final manipulation, once or successively to about 30—50° C. above the intended working temperature, and allowing to cool slowly from this temperature. An oil bath is especially suitable for this operation.

There has been, and in fact there still persists, a certain element of scepticism and prejudice against the adoption of instruments working on the bimetal principle, and it is frequently assumed that their use is only justified in cases where accuracy is of secondary importance. In many instances such an opinion has been formed because the peculiar inherent characteristics of this material have not been judiciously applied—namely, the choice of components, the process of manufacture, method of handling and use, and especially the choice of adjustment.

When, however, the present position of the technique of the manufacture and operation of bimetal—which this article has attempted to survey,—together with the points outlined above, are fully realised, it will readily be appreciated that bimetals are capable of producing results of extremely high precision in instruments which are simple and at the same time reliable.

The author received valuable help in carrying out the numerous tests from Messrs. Grunert and Hagemann, to whom he expresses his sincere gratitude.

New Alloys and Machine Tool Design

(*Continued from page 58*).

non-ferrous, the ferrous, the metallic and non-metallic, and the carbon elements are revealed as they are found in most of the familiar cutting materials and in some native and synthetic compounds capable of being formed into cutting tools :—

—	Metallic.	Non-metallic.	Iron.	Non-ferrous.	Carbon.
Common tool steel	98·5	1·5	98	2	1
Low-tungsten steel	97·5	2·5	88	12	2
Medium-tung. steel	99	1	81	19	0·6
High-tung. steel ..	99	1	76	24	0·7
Tung. van. cob. st.	98·5	1·5	64	36	1
Tungsten carbide .	99	1	0	100	?
Stellite	99	1	0	100	0
Corundum, emery	0	100	0	100	0
Sapphire, ruby ...	0	100	0	100	0
Aluminium oxide .	0	100	0	100	0
Silicon carbide ...	0	100	0	100	30
Diamond.....	0	100	0	100	100

Aluminium oxide and silicon carbide are synthetic compounds, the product of the electric furnace. Emery and corundum, under the trade names "Carborundum," "Aloxite," "Alundum," and many others, are abrasives, though the particles act as true cutting tools.

The diamond and the sapphire are in regular use as cutting tools, the diamond in particular ever growing in favour for light work on hard and abrasive materials.

At the end of our list stands pure carbon, in the diamond—a non-metallic element, yet the most efficient light-cutting material and most resistive of wear. At the beginning might have been placed pure iron, had we regarded it as fit for cutting anything much "harder than butter"—wholly metallic. Midway stands Stellite, almost entirely metallic, containing neither iron nor carbon, and tungsten carbide, with no iron and little carbon, yet in hardness both falling little short of the diamond, their cutting qualities in a rather "heavier sense" exceeding those of the diamond. Follow the non-metallic native compounds, corundum and emery, and sapphire and ruby, then the synthetic compound, aluminium oxide, all of them iron- and carbon-free. Near the end of the list is silicon carbide, non-metallic but carbon-bearing, in hardness approaching the diamond.

Having merely scanned the list, we might well ask ourselves upon what does hardness, strength, and tenacity really depend, even if we do know in what way each of the elements functions. But careful analysis, though it will not disclose the inner reasons, will at least reveal to us that all the iron-bearing materials are superior to those lacking iron, in those properties that heavy and intermittent cutting demands, but that iron is not only non-essential, but rather detrimental for the lighter and steadier cuts.

That none of our modern, perhaps none of our "dead" ferrous cutting metals contain or contained less iron than 64%, and had cutting properties almost identical with those of some non-ferrous materials, ought to give the physicist furiously to think whether further to reduce the iron content might be beneficial. Why should there be a gap between 64% and 0% is an intriguing demand, particularly as with every reduction down to 64% improvement is shown by the performances of the steel.

(*To be continued*).

Factors Influencing the Design of Normalising Furnaces

By E. E. Griffiths, A.M.I.Mech.E.*

THE technical advantages of normalising as compared with box annealing in the manufacture of most qualities of sheets and tinplates are well known, but whether the adoption of the normalising process can be made to pay or not in the manufacture of any particular type of sheet or tinplate is, of course, dependent on the selling price of the product, the operating cost of the furnace used, and the number of times during its manufacture the sheet or tinplate must be normalised, compared with the number of box-annealings required to produce a sheet of similar stamping quality. The author examined the factors which must be considered in the design of a normalising furnace in a paper presented recently at a South Wales branch of the Institute of Mechanical Engineers.

Up to the present time the high operating cost of existing types of normalising furnaces, and also the lack of flatness of thin sheets treated by them, has restricted their commercial use to the treating of sheets which are of a minimum thickness of approximately 26-gauge, and which, due to their super-stamping qualities, can be sold at high prices, such as, for example, sheets for pressing into motor-car bodies.

Description of Principal Types of Normalising Furnaces.

Normalising furnaces differ in many respects. As, however, the type of conveying mechanism is the principal factor in permitting or preventing the incorporation of desirable features in the design of the furnaces, the description was confined to the type of conveyor employed.

Rotating Disc Conveyor.—In this furnace the sheets are conveyed on a series of rotating discs mounted on shafts running transversely across the furnace hearth. Fig. 1c shows the general arrangement of a normalising furnace of this type. The discs on which the sheets are carried through the furnace and cooling chamber are made of suitable material to withstand the temperatures of the various zones in which they are located. The shafts on which the discs are mounted are water-cooled, and rotate in bearings mounted outside the furnace walls, and in many cases these water-cooled shafts are surrounded by insulated muffs.

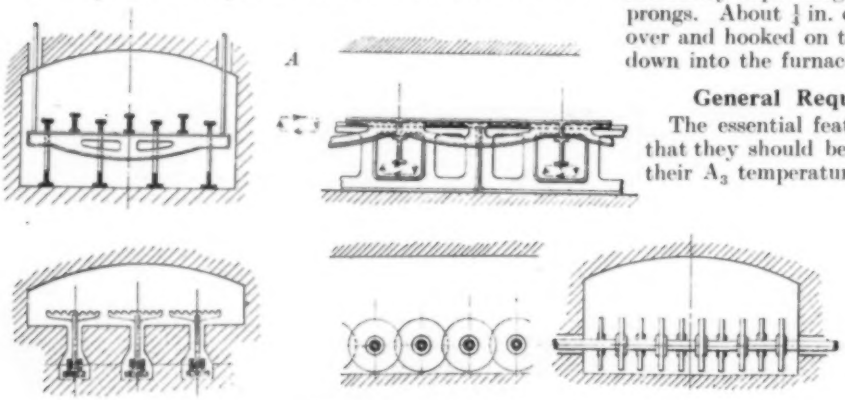


Fig. 1.

Walking Beam Conveyor.—A furnace having this type of conveyor is shown in Fig. 1A. The conveyor consists of movable beams, the top faces of which normally rest below the level of the furnace hearth, these beams being operated mechanically. When in operation, they are first lifted vertically above the hearth level, moved forward a short distance, then lowered beneath hearth-level, and removed back to the original position. The result of this movement is to raise the sheets off the furnace hearth, move them forward, and then lower them on to the hearth, this cycle being regularly repeated.

Continuous Conveyor.—There are two types of furnace employing a chain continuous conveyor. In one type the sheets are carried through the furnace in a horizontal position, and in the other they are carried in the vertical position, suspended from the conveyor by their upper edges. In the best-known types of horizontal furnace having a continuous conveyor, the conveyor chains are situated at the bottom of longitudinal slots in the furnace hearth, their return path being through a pit under the furnace. Fig. 1B shows the general design of this type of furnace. Blades made of heat-resisting metal are fixed to the conveyor chain and project upwards through the slots, their upper edges projecting into the furnace. The sheets being treated rest on top of these blades, and, thus supported, are carried through the furnace and cooling chamber.

In a furnace through which the sheets are carried by being suspended vertically from a continuous conveyor, the conveyor runs in a longitudinal and comparatively cool chamber formed between the side walls and the roof, as shown in Fig. 2, and its return portion runs in an accessible position alongside the furnace. Prongs made of heat-resisting metal project into the furnace through a narrow slot in its upper portion, special heat-resisting steel hooks and safety clips being bolted on to the lower ends of these prongs. About $\frac{1}{4}$ in. of the top edge of each sheet is bent over and hooked on these hooks, the whole sheet hanging down into the furnace chamber.

General Requirements of all Normalisers.

The essential features of all normalising furnaces are that they should be capable of heating the sheets above their A_3 temperature, and that the rate of heating and cooling should be controllable; each individual sheet of any particular gauge and specification should be treated alike. The physical condition of the finished sheet, as well as its mechanical properties, is of importance. It is, therefore, desirable that the surface of the sheets should not be damaged either by scratching or pitting, or by excessive oxidisation. The sheet should be delivered from the furnace as flat as possible.

Process Requirements.

Due to the amount of heat which has to be absorbed through unit area of sheet exposed to the heating medium, the time taken to heat thin sheets for any given set of furnace conditions varies directly as the thickness of the sheets. The period which the sheets are in the furnace is, therefore, varied to suit the thickness of sheets being treated by regulating the speed of the conveyor.

The actual heating and cooling cycle is governed by the temperatures at various points along the length of the furnace and cooling chamber, and in order to obtain accurate control, the furnace should be fired through a series of burners distributed down its length, with an

* *Messrs Stein & Atkinsons, Ltd.*

independent means of adjustment for each burner. The maintenance of constant furnace conditions for any given burner settings may be assured by the use of either a controlling pyrometer or by the provision of a pressure regulator, which will keep a constant delivery pressure of the gas and amount of gas supplied to the furnace for any given valve setting.

The rate of cooling of the sheets during the first part of the cooling cycle can be satisfactorily controlled by adjusting the amount of furnace exhaust gases drawn into the front section of the cooling zone. Further, the amount of excess air required for combustion under any set of conditions is less when hot air is used than is the case if the air supply is cold. Quite apart from any consideration of saving of heat which would otherwise be wasted, this effect of reducing the excess air needed, and consequently reducing the oxidisation of the surface of the sheets, is itself enough to justify the use of an efficient recuperator for preheating the combustion air.

The author stressed the importance of evenness of temperature throughout the sheets. This may be obtained by any system of surface combustion, provided clean gas is used. If ra · gas is used, a perforated roof or cross firing is necessary for the horizontal furnaces, and in the vertical type of furnace, the flame is arranged to flow up recesses in the walls and down the sheets to exhaust ports in the furnace floor. In regard to the reduction of surface scaling, the author stated that, in a furnace in which the combustion section is well designed, the greater part of any scale which is produced on the sheets during the normalising process is formed while the sheets are passing through the rear part of the cooling zone, when this is filled with furnace exhaust gases.

Gas generated in a small anthracite or coke producer, working with an air blast only, appears to be the most suitable medium with which to fill this rear part of the cooling chamber if scaling of the sheets is to be prevented.

Prevention of Damage to Surface of Sheets.

The furnace should be designed so that the surface of the sheets is not damaged during normalising. In horizontal furnaces, particularly the type having a rotated-disc conveyor, the conveyor has been found to cause depressions in the surface of the hot sheets, these depressions very much resembling "roll marks" in appearance. The percentage of wasters caused by these defects was originally high, but has lately been reduced by placing a carrier-sheet between the conveyor and the sheets being treated. In

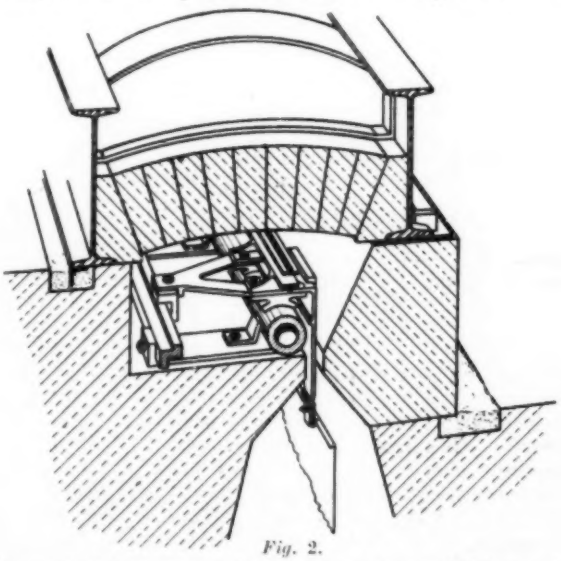


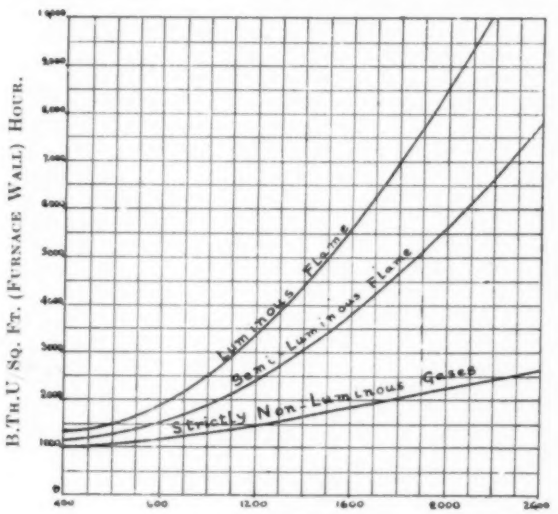
Fig. 2.

the vertical furnace, as the sheets are suspended from the conveyor at only a few points at their extreme end, no mechanical damage can be done to their surfaces, and no carrier-sheets are required.

The flatness of all products is important, and when treating thin sheets in the horizontal furnace, the use of stiff H.R. steel carrier sheets is the most economical way of keeping the stock flat. In the vertical furnace, on the other hand, the sheets hang flat, and their tendency to do so is actually greater in the case of thin sheets than of thick ones.

Operating Costs.

The above factors deal with the requirements which a normalising furnace must fulfil in order that the heat-treatment and physical properties of the sheets may be correct. Assuming these requirements to be satisfied, the operating cost of the furnace determines its applications.



METAL ANNEALING °F

Fig. 3.

The type of conveyor has a direct effect on the fuel cost, by influencing the ratio of the amount of heat absorbed by the "dead" material to that absorbed by the sheets; its indirect effect on this cost, as it limits the type of fuel which can be used, the maximum furnace temperature permissible, and the time in which the sheets can be heated.

The thermal treatment required by the sheets does not impose any limitation to the rate at which the sheets can be heated, the crystal size being governed by the soaking time and the initial rate of cooling. If overheating of the conveyor can be overcome, the rate at which thin sheets can be heated in a normaliser is limited only by the rate at which the heat can be transferred on to the sheet, and not by that taken for the heat to penetrate from the outside to the centre of the mass of metal as in box-annealing.

The rate of heating affects the size of furnace required and consequently the heat lost through the furnace walls, the fuel needed to heat up the furnace after a week-end stoppage, the ground space occupied by the furnace and the upkeep and repair costs of the furnace and conveyor.

Fuel Cost.—The amount of heat absorbed by the conveyor, the conveyor cooling water and carrier sheets should be reduced to a minimum, not only on account of the heat lost, but because the "nett" output of the furnace is reduced: as carrier sheets can be dispensed with in the vertical furnace, this is a distinct advantage.

In the rotating-disc and walking-beam type of furnaces the conveyor is constantly in the furnace, and consequently does not carry heat away from the furnace chamber. The water cooling of the transverse shafts in the disc type of furnace absorbs heat, but the amount is kept relatively low in recent designs of furnace by placing "muffs" of insulating material around these shafts.

In furnaces of either the vertical or horizontal type which are fitted with a continuous conveyor, this conveyor, during its passage through the furnace, has its temperature increased and heat is consequently absorbed from the

furnace. Water cooling of any parts of a continuous-chain conveyor which enter the furnace chamber is not necessarily due to the low average temperature at which these parts are maintained, due to them cooling down on their return passage outside the furnace. The principal point to be observed in the case of a continuous conveyor, is that only a small portion of the conveyor should project into the furnace chamber, and that the main portion should be situated in a cool position, this arrangement keeping the amount of heat absorbed by the conveyor at a minimum.

In furnaces which are fitted with a continuous conveyor, it is possible to use raw producer gas as a fuel, since the conveyor, due to its mass compared with the sheet it carries and to the relatively short time it is in the furnace, does not reach furnace temperature, and is not, therefore, attacked by the sulphur compounds in the fuel. The factor which influences the type of fuel used in a normaliser is the temperature at which the H.R. metal in the conveyor is attacked by sulphur compounds in the furnace gases. When this temperature is below that of the furnace it is necessary to use a fuel with a low sulphur content, such as gas-oil, town's gas, or washed producer gas for firing furnaces whose conveyors are always in the furnace, and which attain furnace temperature. These fuels are costly and their use, therefore, adds to the cost of annealing.

The rate of heat transfer from a luminous flame is much greater than that from a non-luminous flame, as will be seen by Fig. 3, and in order to obtain the maximum output from any size of furnace, the fuel used should be one which burns with a luminous flame at the required temperature. The tar and small carbon particles in raw producer gas cause the desired luminosity of the flame of this fuel.

The rate of radiation of heat from one body to another varies as the difference between the fourth powers of the absolute temperatures of the two bodies, so that a small increase in flame temperature gives a large increase in the rate of heat transfer. Fig. 4 shows the rate of heat transfer due to the combined effect of radiation and conduction for various flame and sheet temperatures. The difficulty of maintaining combustion and high flame temperature without the deposition of soot in the presence of the cold sheets

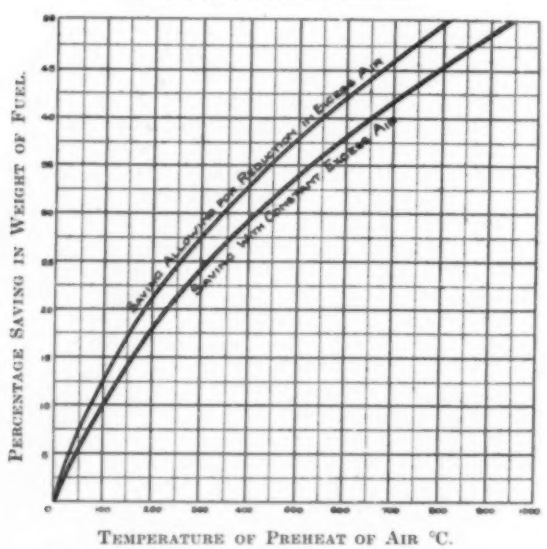

SAVING DUE TO RECUPERATION.
PERCENTAGE SAVING IN WEIGHT OF FUEL.
SAVING ALLOWANCE FOR REDUCTION IN EXCESS AIR
SAVING WITH CONSTANT EXCESS AIR
TEMPERATURE OF PREHEAT OF AIR °C.

Fig. 5.

in the front end of the furnace can be eliminated by highly preheating the combustion air, preferably in a continuous recuperator.

In the types of furnaces having their conveyor always in the furnace, this front-end temperature is limited by the temperature which the metal of this conveyor will stand. A conveyor of the chain type does not limit the maximum front-end temperature, as the conveyor does not reach furnace temperature.

In order to obtain the maximum rate of heat transfer to the sheet for any given furnace conditions it is essential that each side of the sheets be exposed to the full furnace temperature. The efficiency of application of heat to the

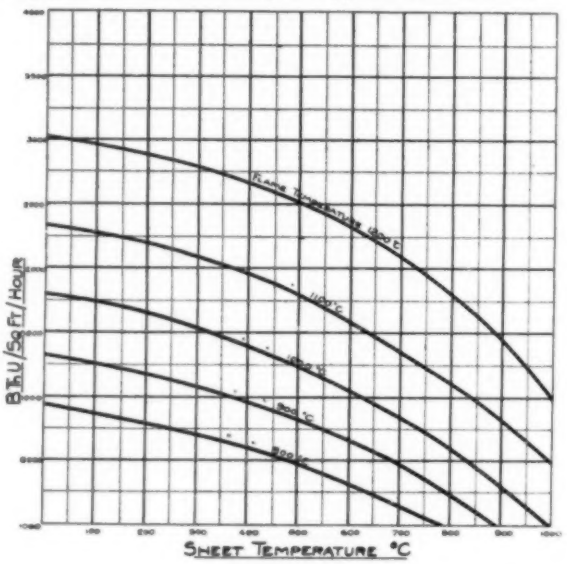


Fig. 4.

underside of the sheets in a horizontal furnace is, however, restricted by the conveyor. Care must be taken in such furnaces that heat is not lost from the underside of the sheet, either through drawing cool exhaust gases under the sheet, through the cooling effect of the conveyor, or from heat conducted away through the furnace hearth. These precautions are not necessary in the vertical furnace, as each side of the sheet is exposed to the full furnace temperature.

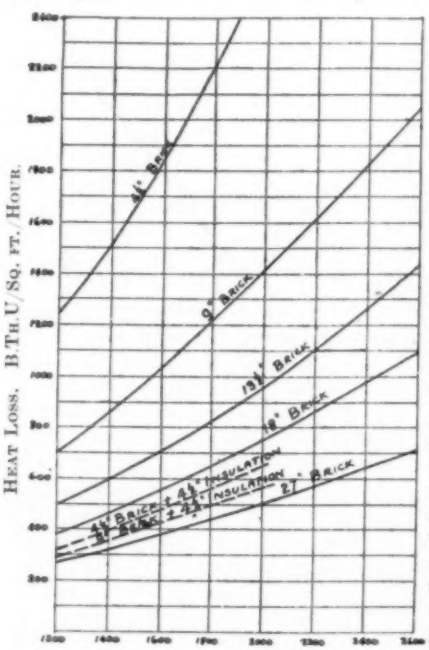


Fig. 6.

Recuperation.—A continuous recuperator should be attached to the furnace for the purpose of transferring to the air for combustion, the heat from the exhaust gases. The saving is twofold, being due not only to the heat put back into the furnace in the combustion air, but due also to the smaller quantity of exhaust gases going to waste. Fig. 5 shows the saving in fuel which may be effected by preheating the combustion air to any given temperatures—these curves being specially plotted for the exhaust temperatures encountered in normalising furnaces.

Insulation.—In accordance with modern furnace practice, the heat lost through the furnace exterior should be reduced by the use of insulation where necessary and economical.

(*Continued on page* 68.)

Some Non-ferrous Engineering Alloys

By Wesley Lambert, A.K.C.

Resistance to corrosion, thermal conductivity, anti-frictional qualities, dependability, machinability, specific gravity, and artistic attractiveness are some of the factors favouring the use of non-ferrous alloys which Mr. Wesley Lambert discussed in a paper presented recently at a meeting of the Institution of Engineers and Shipbuilders in Scotland, and from which the following has been extracted. He confined himself to the heavy non-ferrous alloys used in engineering practice.

OF the non-ferrous engineering alloys in demand today, by far the greater weight is comprised of yellow metal. Yellow-metal alloys may be divided into two categories—the high-tensile and the lower-tensile brasses. In the form of castings, the mechanical properties to be expected of the high-tensile brasses range from 12 to 25 tons per sq. in. yield, 28 to 45 tons per sq. in. ultimate strength, and 25 to 12% elongation, the figures being minima for the respective grades of metal included in the specification. The minimum figures for the two grades A and B respectively of the high-tensile brasses in the worked condition are 15 and 18 tons per sq. in. yield, 30 and 35 tons per sq. in. ultimate strength, and 25 and 20% elongation. The commercial high-tensile yellow metals are almost exclusively confined to two types of alloy—namely, manganese bronze and aluminium bronze. The lower-tensile yellow metals are binary alloys of copper and zinc, usually in the proportion of 60 copper, 40 zinc, or 70 copper, 30 zinc, with or without the addition of small percentages of tin and other metals, these brasses being commonly referred to as naval brass, cartridge brass, condenser brass, muntz metal, delta metal, etc. A brass of the composition 76 copper, 22 zinc, and 2 aluminium has recently been introduced as a corrosion-proof condenser tube alloy.

Manganese Bronze.

Manganese bronze, or to use a more correct nomenclature, manganese brass, is a complex alloy of the 60-copper 40-zinc type, to which comparatively small percentages of other metals are added, replacing in part either the copper or zinc, as the case may be. These additional metals include tin, iron, manganese, aluminium, and nickel, and in a properly compounded manganese brass confer upon the alloy greatly enhanced mechanical properties, resulting in these complex brasses being in great demand for parts subjected to severe duty. Manganese bronze may be forged, stamped, rolled, extruded or drawn, and its strength may be further improved by suitable thermal treatment. The best manganese bronze for castings is rarely compounded in the ordinary non-ferrous foundries, being more often purchased in the form of ingot metal from foundries making a speciality of this type of bronze, but, notwithstanding the repeated warnings of experienced metallurgists, attempts have been made from time to time by foundrymen desirous of making castings in these complex brasses from the one melting, without previously making into ingots and remelting the alloy. Such a procedure almost invariably leads to failure, and after a few abortive attempts to do the almost impossible, the foundryman is inclined to regard with disfavour each and all of the complex brasses.

The direct making and teeming of manganese bronze into foundry moulds is conducive to an increase in foundry "wasters," and a melt of ingot metal drawn from a large stock of a reputable maker is more likely to average itself out than a single charge of metal compounded by less experienced metal mixers.

The composition of commercial manganese bronze will be found in general to be within the following limits:—

	Per Cent.
Copper	50 — 60
Aluminium	Traces — 5
Tin	Traces — 1½
Iron	Traces — 2
Manganese	Traces — 8
Nickel	Traces — 5
Zinc	Remainder

Lead, arsenic, bismuth, or antimony, even in small quantities, are undesirable constituents. The composition, the state of cleanliness of the metal, the freedom or otherwise from gas and "draws," the character of the micro-structure, and the grain size, are the important factors which determine the strength of a manganese bronze.

Manganese bronze is as strong as steel—tensile tests showing a figure up to 50 tons per sq. in. ultimate strength even in the sand-cast condition,—and is in increasing demand for all castings where great strength is a requisite and the use of steel is not considered desirable. These parts include marine propellers, gland rings, nuts and cone caps, conning-tower castings, torpedo tube casings, marine-engine fittings, pontoon and boat fittings, gun-mounting and ordnance fittings, high-pressure cylinders, valves, engine frames, locomotive axle-boxes, rotor end caps and rings, impellers, mill and machinery parts, stay and bracket castings, gear-wheels, rim castings, racks, kneading machines, pulp beaters, etc. In the worked condition, whether rolled, extruded, forged or stamped, manganese bronze has many applications, and may be used confidently whenever it is desirable to exclude steel or other ferrous alloys.

Aluminium Bronze.

Aluminium bronze is essentially an alloy of copper and aluminium, the copper predominating. Throughout a number of years, the most generally accepted proportion in which the two metals have been compounded is in the well-known ratio of 90 parts by weight of the former and 10 of the latter metal: aluminium bronze made in this proportion is still used as a casting alloy in a few foundries, whenever high-tenacity non-ferrous bronze is specified. A tensile strength of 32 to 35 tons per sq. in., with an elongation of 20 to 25% in a 2-in. acting length is nowadays expected from a well-run cast metal. The elastic limit should approximate to half the braking load, and the reduction of area at the fracture should not fall short of 25%.

The composition of commercial aluminium bronze of casting quality varies between somewhat wide limits, and in many cases the additional elements beyond the essential metals, copper and aluminium, bring the bronze within the category of the complex alloys. Certain alloys of the aluminium-bronze series are very susceptible to heat-treatment, and the mechanical properties of such alloys may be improved, or at least modified, by suitable thermal treatment. In the manufacture of straight aluminium bronzes (copper and aluminium) care must be exercised in selecting the constituent metals. Electrolytic copper and a good quality of aluminium are essential when the best results are desired. The usual percentage of aluminium is 10 to 12, and the latter figure should rarely be exceeded. Iron, manganese, and nickel are common constituents in aluminium bronzes; nowadays the most frequently used alloys of the aluminium bronze series invariably contain low percentages of these other elements to the extent of 1 to 4, associated with 7 to 10% of aluminium. For small sand castings, copper 89, aluminium 10, iron 1, is representative of good practice; for large sand castings the iron may be increased to 4% at the expense of either the copper alone, or the copper and aluminium. It is not advisable to exceed the percentage of iron stated except for very occasional work. In compounding the constituent metals great care must be exercised to guard against

oxidation of the copper during the melting of this element. Considerable skill is required in making a good aluminium bronze ; want of skill is denoted by the presence of oxides, especially aluminium oxide (Al_2O_3), a white powder, and by segregation troubles.

Aluminium bronze may be subjected to stresses of an order little less than its ultimate strength, as determined by the ordinary tensile testing, and will be found to resist failure by fatigue ; manganese bronze, on the other hand, when subjected to alternating or repeated stresses, can only be relied upon to resist failure under fatigue provided the stress applied is within the elastic limit of the bronze as determined by careful observation. Furthermore, for certain purposes, more particularly in chemical engineering, aluminium bronze is found to be more resistant to corrosion than manganese bronze.

As a casting alloy, apart from die-castings, aluminium bronze is not greatly favoured in the non-ferrous foundry. Dross, shrinkage, gas cavities, and isolated patches rich in aluminium oxide are common findings in defective castings. For this reason, coupled with the necessarily extravagant use of metal, an order for castings in aluminium bronze is not welcomed by many foundrymen. It is only by the strictest attention to details throughout the making of the metal, the moulding of the part, and the teeming of the alloy, that even a fair measure of success may be expected.

Gunmetal.

Of the true bronzes—that is to say, the copper-tin alloys —two categories only need be considered at length—namely, gunmetal and phosphor bronze.

Excluding brass, the former is perhaps the best known of all the cupreous alloys. The composition of gunmetal conforms either to the well-known Admiralty mixing of 88 copper, 10 tin, 2 zinc, or slight modifications of this mixing, in which the zinc is raised by 1 or 2%, and small quantities of lead and phosphorus are introduced. The mechanical properties of such alloys as those included in this category are : Ultimate strength 17 to 22 tons per sq. in., elongation 18 to 25% in a length of 2 in., Brinell hardness 70 to 75. The specific gravity is about 8·5. The popularity accorded to Admiralty gunmetal by the engineer is more grudgingly accorded by both the metallurgist and the foundryman. All foundries are not equally happy in their experiences with Admiralty gunmetal as a casting alloy, and unauthorised liberties, such as an increase in the percentage of zinc to 4%, or an addition of lead to the extent of 1% or more, etc., are often resorted to in order to cover inability to make successful castings in the recognised mixture. Good Admiralty gunmetal cannot be made by slipshod methods or from contaminated scrap metals. " Best selected " ingot copper, carefully melted under non-oxidising conditions, followed by the introduction of the warm dry zinc, gentle stirring, and, after a short interval, the addition of the requisite amount of tin, presents the proper sequence to be observed in compounding the metals into a reliable alloy. Admiralty gunmetal, although containing 2% of zinc, comes almost within the category of the tin bronzes, the microstructure of which may be modified by thermal treatment, and annealing is therefore sometimes resorted to when toughness is the first consideration. In this connection, it must be borne in mind that owing to the change in the micro-constituents brought about by such thermal treatment, some of the mechanical properties, as, for instance, the hardness, tensile strength, elongation, degree of malleability, the coefficient of friction, and the resistance to abrasive wear, may be very materially altered from the corresponding figures obtained from the metal before being subjected to heat-treatment. The author has obtained from suitably heat-treated test-bars of Admiralty gunmetal ultimate stress figures as high as 25·4 tons per sq. in., accompanied by an elongation of 74% in a 2 in. acting length.

Phosphor Bronze.

Phosphor bronze, in common with other special bronzes, such as vanadium bronze, titanium bronze, manganese bronze, etc., includes alloys in which the distinctive element from which the particular bronze derives its name has been introduced into the alloy solely as a scavenging agent, and it may be present in the resulting alloy only to the extent of " traces," analysis often failing to detect even these traces. In the author's experience, covering the examination of a great number of cast phosphor bronzes, 2% of phosphorus is the highest content of this element, and in the majority of cases the figure was well under 1%. Mr. A. Philip, Admiralty chemist, as a result of having tabulated the composition and mechanical tests of a very large number of castings in phosphor bronze, proposed a chemical specification for this alloy in which the maximum percentage of phsophorus is 0·6 and the minimum figure 0·3%; the tin content being 7·4 to 9·7%. A tensile strength of not less than 17 tons per sq. in., and an elongation in a 2 in. acting length of not less than 20% is mentioned by Philip in this connection.

In those cases where a high degree of resistance to wear and a low coefficient of friction combined with strength are the most desirable properties, the content of tin may well be increased over the Admiralty percentage, and the phosphorus may be raised to as much as 1·5%. Such bronzes fall within the category of the bearing metals, and the microstructure is found to conform to the recognised structure of a bearing metal, inasmuch as a micro-constituent segregates out, forming hard particles which, more or less uniformly distributed, are found embedded in a softer matrix.

A distinction should be made between phosphorised bronzes and genuine phosphor bronze. For castings, a composition closely approximating to copper 89, tin 10·5, phosphorus 0·5 is recommended. The mechanical properties of an alloy of this mixing should show a minimum ultimate strength of 17 tons per sq. in., a minimum elongation in a length of 2 in. of 10%, and a Brinell hardness of 80 to 90. The specific gravity will be about 8·6. Chill-cast phosphor bronze sticks, both solid and cored, are in great demand as a bush material whenever resistance to abrasive wear is desirable. Chill-cast and centrifugally-cast phosphor bronze is much favoured for gear-wheel blanks, particularly in the automobile industry, and British Standard Specification is now in course of preparation to govern the composition and mechanical tests to be specified for such. It is not uncommon to associate a fairly heavy percentage of lead in those phosphor bronzes intended for slide valves. A lead content about 7% associated with a tin content of 10% is admissible.

Lead Bronzes.

Lead bronzes constitute an important series of non-ferrous alloys, the use of which is confined almost entirely to the engineering industry. The function of the tin is to harden the copper and thereby to form a hard matrix, in which the incompatible insoluble lead segregates out during the solidification of the alloy, forming pools of free lead. Thus, a heterogeneous alloy is formed in which a soft constituent is encompassed by a harder constituent. The lead bronzes, by virtue of the character of their structure, are favourably regarded, and rightly so, for bearings.

The composition of the lead bronzes differs within wide limits. A typical high-class lead bronze is represented by copper 80%, tin 12%, and lead 8%. Higher lead contents are quite common, and bronzes containing as much as 45 to 50% lead are not unknown. In general, the copper content falls between 65 and 80%, the tin content 5 to 10%, and the lead content 10 to 30%. An alloy of 75 copper, 10 tin, 15 lead, makes an excellent bearing bronze of almost universal application wherever unlined bronze bearings are permissible. Upon the size and uniform distribution

of relatively small segregates of lead depends to a large extent the successful functioning of lead bronzes as bearing metals.

Monel Metal.

Monel metal is typical of a group of alloys more akin to the white metal alloys of the German silver type than to cupreous bronzes. Monel metal, when at its best, is a pleasing alloy, almost indistinguishable from nickel, and having both physical and mechanical properties which are very attractive to the engineer. Its ultimate strength, elasticity, and ductility, combined with a high degree of resistance to corrosion, have led to the adoption of this metal for many engineering parts, where cost is not a first consideration.

Monel metal is an alloy of the approximate composition of 67% nickel, 28% copper, the remaining 5% being made up of iron, manganese, etc. When first introduced, it was a product obtained during the process of winning nickel from its natural ore, hence the references to the alloy as being "a natural alloy." Nowadays the alloy when synthetically compounded under metallurgical control is quite equal, if not superior, to the so-called "natural alloy." In the cast condition average test results may be expected to give a yield of 16·5 tons per sq. in., ultimate strength 32 tons per sq. in., and elongation 30% on a 2-in. acting length: the corresponding figures for the alloy in the worked condition are 24 tons, 40 tons, and 35% respectively. Its elastic limit under both tensile and compressive stresses is high, and its strength at high temperatures is not reduced in a like ratio to that of the more commonly employed non-ferrous alloys. The alloy is, therefore, rightly recommended for castings and other parts which have to do duty at temperatures where other non-ferrous alloys would be inadmissible. On account of its high corrosion-resisting properties, combined with its strength and high elastic limit under both tensile and compressive stresses, Monel metal, either in the form of rolled or forged rod, is in considerable demand for use as pump rods, and also for propeller shafts for small craft, two applications which alone suggest a high-duty material.

Anti-friction White Metals.

Mention has already been made of one type of bearing metal—namely, the bearing bronzes,—but these notes would not even approach completeness without a few references to another type of bearing metal—a type familiarly known as "Babbitt metal," but more correctly designated anti-friction white metal. As a result of many investigations carried out upon both promising and less promising materials, much useful information has been acquired. The application of the knowledge obtained comes more within the province of the metallurgist than the engineer, and the former should be in a position to formulate a specification covering not only the chemical composition, but also the desired microstructure of a bearing metal.

Desirable Properties of Bearing Metal.—A metal is not necessarily a good bearing metal because it is comparatively soft, as, for instance, alloys of the Babbitt class, or because it is hard, like some of the bronzes. Low coefficient of friction, good thermal conductivity, resistance to abrasive wear, and sufficient strength and rigidity to stand up to the duty, are among the more important properties demanded of a bearing metal.

Characteristics of Good Bearing Metal.—A good bearing metal, therefore, should possess in a marked degree the following characteristics:—

1. The metal must be strong enough to sustain its maximum load.
2. It must not heat rapidly.
3. It must be capable of being made into sound castings.
4. The coefficient of friction must be low.
5. High resistance to abrasive wear must be guaranteed.

The commonly accepted bearing alloys which fulfil the above conditions may be roughly divided into two categories—namely, (1) bronzes, and (2) white metals. The hard micro-constituent in the case of the bronzes is a segregated copper-tin compound, plus a phosphorus compound should this latter element be present in appreciable amount. In the white metals, the hard cubical crystals of tin-antimony and the star-shaped crystals of copper-tin are found.

The anti-frictional and also the wear-resisting qualities of the true bearing bronzes and white metals depend almost entirely on the amount, the character, the form, and also on the uniform distribution of the segregated particles. Chemical analysis fails to throw much light on the reason of this successful duty, but the microscope invariably reveals the presence of the correct percentage of segregate of normal formation uniformly distributed throughout the mass forming the matrix. Emphasis is, therefore, given to the need of the alloy being "properly compounded." The manufacture of bearing bronzes is not merely a question of melting certain metals together, but is one of scientific knowledge and control, and only those alloys the manufacture of which is thus supervised should be adopted by the engineer. This is indeed true not only of the cupreous bronzes, but also equally true of white metals for use as lining metals.

Qualities of Ideal Lining Metal.

1. *Metallurgical.*—(*a*) The constituent metals must be of a high degree of purity (less than 0·1% of certain impurities would ruin an otherwise excellent lining metal).

(*b*) The alloy must be of correct composition and correctly compounded.

(*c*) The metal should admit a wide range of melting and casting temperatures, in order to meet the varying conditions of lining necessitated by different types of bearing.

(*d*) The lining metal must be free-running, without undue formation of dross.

(*e*) The alloy must not be liable to abnormal segregation of any of its constituents.

(*f*) Low shrinkage of the metal is very desirable.

(*g*) Good adhesion to the shell is a *sine qua non*. (The qualities indicated under (*f*) and (*g*) are essential if the lined shell is to "ring" solid.)

(*h*) The metal must be free from extraneous matter—that is, dross or scum, foreign matter such as sand, etc.

(*i*) The white metal should be as far as possible fool-proof.

2. *Mechanical.*—(*a*) The metal should be soft and plastic to a sufficient degree to accommodate itself to the inequalities of the moving parts, and thus afford them an even bearing.

(*b*) The lining must be of sufficient hardness to prevent rapid abrasion.

(*c*) The white metal must be able to stand up to the desired load without undue flow.

(*d*) The metal must not be unnecessarily brittle, or there will be a tendency to crack.

(*e*) The alloy should not be liable to disintegrate or break down under hammering or planing effect.

3. *Physical.*—(*a*) The microstructure of the metal should be such as to conform with the best anti-frictional conditions.

(*b*) The metal should be capable of taking and preserving a surface of high polish.

(*c*) If practicable, the metal should be, *per se*, of a more or less self-lubricating type.

(*d*) The metal should possess good thermal conductivity.

In modern practice it is found that the basic metal of anti-frictional white metals is a controversial point. Many engineers favour a tin base, and a considerable number favour the cheaper lead base metals. A correctly compounded and properly run tin base lining, capable of sustaining the same static load as an equally correctly compounded and properly run lead base metal, possesses in a greater degree the virtues associated with bearing

metals. The tin base Babbitts are therefore specified, and rightly so, in the author's opinion, for all high-class machinery, and especially for high-speed heavy-duty work, notwithstanding that the lubrication may be considered, and probably is, of the highest efficiency.

Lead Base v. Tin Base White Metal.—The author is fully aware that the subject, "Lead base white metal versus tin base white metal" is a very debatable one; but having had the advantage of inspecting hundreds of lined bearings, some of the latter having done much service, he is of opinion that a lining metal with a liberal percentage of tin is desirable for all high-class work. Brasses lined with white metal compounded with a generous proportion of tin were invariably found to have maintained a well-polished, mirror-like surface. Mention is frequently made of the lubricating properties of lead, but, so far as the author is aware, there is little or no ground for claiming such a property for lead; but misconception is also rife regarding the comparative hardness of the tin base alloys as compared with that of the lead base alloys. A tin base alloy need be no harder than a lead base alloy; it is all a question of the proportion and character of the hardening elements when compounding each type of metal. Certain it is, however, that for equal hardness in the two types as ordinarily compounded, the lead base metal will be the more likely to be the more brittle of the two. Many of the lead base metals at present on the market are harder than some of the tin base alloys. An addition of as much as 15 to 20% of antimony enters into the composition of the lead base Babbitts, antimony acting as the hardening element. Some of these alloys are of a very brittle character, and when acceleration is rapid this brittleness of the lining metal may result in the cracking and breaking away of the lining from the bearing shell, whereas a metal of the same hardness, but having a generous proportion of tin in its composition, being tougher, will not be so liable to fail under like conditions of service.

Recommended Mixtures for White Metal Linings.—The following approximate compositions, in the author's opinion, are likely to fulfil nearly all the requirements of the engineer:—

1. Tin 92, antimony 5, copper 3%. (Conforming to Air Board Specification 2 L.9.)
   Application: Thin linings submitted to similar duty to that prevailing in aircraft machinery.
2. Tin 86, antimony 9, copper 5%. (Conforming to Admiralty Specification.)
   Application: High-duty bearings generally.
3. Tin 75, antimony 5·5, copper 4·5, lead 15%.
   Application: Main bearings and other bearings of generous proportions.
4. Tin 10, antimony 15, lead 75%.
   Application: Slow-running generously proportioned bearings.
5. Tin 69, copper 1·5, zinc 29·5%. (Conforming to Admiralty Specification.)
   Application: Under-sea-water bearings, such as stern-tube liners, etc.

Factors Influencing the Design of Normalising Furnaces

(*Continued from page* 64).

Fig. 6 shows the great reduction in heat lost through insulated walls as compared with plain firebrick. The insulation should be placed as near to the inner surface of the furnace walls as possible, in order to keep the heat capacity of the furnace, and consequently the time taken to heat up the furnace, as low as possible.

Mechanical Upkeep.—The temperature of all wearing parts should be kept low, so as not to destroy the lubricant on these parts, and also to enable them to be made of a cheap material without danger of them warping, breaking, or oxidising. So far as is possible without permitting excessive leakage of gas from the furnace, these wearing parts should be placed outside the furnace. If a conveyor of the chain type be placed outside the furnace it is difficult to prevent leakage of gas from the furnace, and in this case the actual track on which the conveyor runs should be placed in a cool side chamber, only connected to furnace-heating chamber by a narrow slot, through which the part of the conveyor carrying the sheets projects.

Conveyor Feet Moved per Ton of Sheets.—The output of a normalising furnace is the product of the average loading of the conveyor per square foot, the speed of the conveyor, and the width of sheets worked. The wider the sheets worked in a normaliser, the smaller initial and upkeep cost of the auxiliary and driving mechanism per ton of sheets produced per hour. A great advantage is obtained in the vertical normaliser by feeding the sheets with their short edges fixed to the conveyor.

Labour Cost and General Conditions.

The maximum output of each furnace should be maintained, and this can only be obtained by minimising any idle periods necessitated by repairs or by changing from one size or gauge of sheet to the other. To reduce these periods, all mechanical parts should be easily accessible, even with the furnace running, and any adjustments necessary when changing from one size or gauge of sheet to another should be simple, and their number should be a minimum. In order to minimise the labour costs for operating a furnace, the size of furnace installed should, if space permits, be capable of treating the maximum tonnage of sheets which the operator can handle.

Catalogues and Other Publications.

The subject of "Welding tor the Chemical Industry" is an interesting one, but when written by such an authority as F. Leverick, A.M.I.Mech.E., it is not only interesting, but also informative. He states that the welder can only ensure good work if he is supplied with good alloys and with good electrodes, but it is essential that he understands some of the underlying principles entailed in working special alloys for the chemical industry. "The Welding of Monel Metal and Pure Malleable Nickel" is the title of a booklet by N. C. Marples, M.Sc. Those interested should apply for copies of these booklets to Alloy Welding Processes, Ltd.

The Bureau of Information on Nickel has published a booklet dealing with "Nickel in Light Aluminium Alloys." It contains articles on "Aluminium Alloy Y" and "The R R Group of Aluminium Alloys"; a third article describes the manufacture and application of both "Y" and "R R" alloys. The November issue of the *Nickel Bulletin* contains two interesting articles, one on "The Use of Nickel Alloy Steels in the London Omnibuses," and the other dealing with the new heat and corrosion-resisting cast iron, "Nimol." The bulletin, as well as the booklet, can be obtained on application to the Bureau of Information on Nickel, Imperial Chemical House, Millbank, London, S.W. 1.

We have received from Messrs. John Brown and Co., Ltd., a copy of their alloy and tool steel booklet, which contains a full survey of the uses and application of their special steels, both for high speed and tool uses. The booklet is well bound and very well prepared, and its illustrations and charts make it a very interesting publication. It may be obtained on application to their head office, Atlas Works, Sheffield.

We have received from the Workington Iron and Steel Company, a brochure dealing with their new U.C.O. "All-Mine" cylinder irons, which are the latest development of the Workington range of pig-irons. These irons are sold only to analysis, and the brochure contains information as to the range of analyses available. It can be obtained on application to the above company, Moss Bay, Workington, Cumberland.

Messrs. Sanderson Bros. and Newbould have sent us two brochures; one deals with their three high-speed steels, "Saben," "Saben Extra," and "Saben Kerau," and the other with P-I-T-H-O oil-hardening crucible steel. They contain specification details of the steels, together with lists of the uses to which they can be put, and may be obtained on application to this Sheffield firm.

Bright-Annealing by the—— Grünewald Process*

By R. W. Muller.

To maintain a clean bright surface on annealed metal, precautions against oxidation are necessary as well as regularity of suitable temperature.

DURING the current century there have been very important developments in all branches of the metal industry, but the annealing process has not kept pace with the general development. More than 90% of all products are still annealed by the same uneconomical and inexact method as has been used for the past fifty years. The introduction of the electric furnace opened up new possibilities, especially as regards maintenance of regularity of temperature, but the most serious problem—prevention of oxidation of the material being annealed—remained unsolved.

With the old method of bright-annealing, in which the annealing pot is filled with iron borings, electrical heating is too costly, whilst filling the muffle or furnace with a non-oxidising gas, which is frequently of an explosive character, is so costly and has so many disadvantages that it is no longer worthy of consideration. In recent years it has been shown that to obtain a clean surface on annealed metal it is only necessary to take precautions against oxidation during the cooling of the charge. The Vitry method, for example, is based on this, but as it is bound up with the use of non-oxidising gases, it has not been very widely adopted.

The basis of the Grünewald bright-annealing process is the same, but instead of using inert gases to prevent air entering the annealing pot, the latter is made airtight when the maximum temperature is reached: the principle is similar to that used in preserving fruits and other foodstuffs. In construction the Grünewald annealing pot differs from those previously used in that it does not stand on the floor of the furnace, but hangs inside it, being supported by its rim. Also, the charge is not placed directly in the pot, but on a special plate which is fastened to the cover by long tie-rods, the cover serving also to close the furnace. This new arrangement makes it possible—

1. Greatly to reduce the weight of the pot, which need not be so strongly made, as during annealing it is strained only in proportion to its own weight: and
2. To recover part of the heat stored up in the pot and its charge, without the need for costly plant.

The economical advantages are readily seen. Instead of cast steel or special sheet, 20–30 mm. thick, boiler-plate, 6–8 mm. thick, can be used for temperatures up to 750° C. This reduction in the total weight to be heated up alone makes possible a saving of 15 to 20% of the current. The thinner walls offer less resistance to the transference of heat, so that the output of the furnace is considerably increased. In general, annealing pots in electric furnaces have a longer average life than do those in other types of furnace. The life of a Grünewald pot is even longer, as it can be used until the walls are so thin that it is no longer airtight (3–4 mm.). Even then it is only necessary to replace that part of the casing which is exposed to the heat of the furnace, and therefore subject to oxidation, the cover having practically unlimited durability. Consequently, the cost of repairs with the Grünewald pot is only about one-quarter of that with a cast-steel pot which is placed wholly within the heating chamber.

* Translated from "Das Grünewald-Blankglühverfahren" Metallwirtschaft, 20th June, 1930 (No. 25,) by I. Boodgon.

As already mentioned, the Grünewald pot can be used with very thin walls. Hence, that part of the pot which is exposed to the heat can be made of special heat-resisting steel without making its cost too high. The thin walls, the low weight, and the fact that the surface of the pot is always free from oxide, make possible a much more rapid heating and cooling of the charge, so that the number of pots necessary for a given output is much lower. Also, fewer furnaces are needed, so that in addition to the economy in space, the initial cost of the plant, including pots, is much less than for any other plant for the same output, even though the walls of the pots in the former case are made of the more expensive non-oxidising metal.

The annealing pot is closed in much the same way as is a preserving jar, a rubber ring being placed between the rim of the pot and the cover. The ring is cooled by water which circulates in a trough; it is thus prevented from getting too hot, and the same ring can be used about a hundred times. The pot is shown diagrammatically in Fig. 1.

The method of working is as follows:—

The material is placed on the plate, the cover and tie-rods brought over it by means of a crane, and the rods fastened to the plate. The whole is now lifted, brought to the pot, and lowered. The cover is clamped to the pot in such a way that an even pressure is exerted on the whole of the

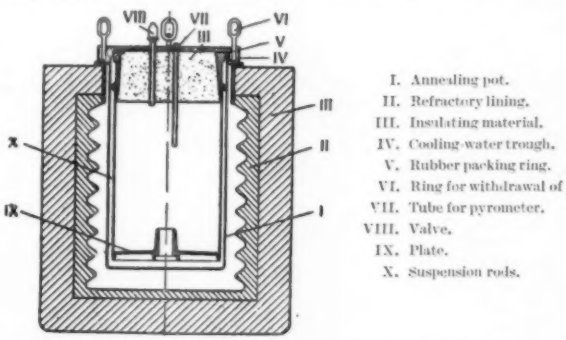


Fig. 1.—Section through Brown Boverie annealing furnace with Grünewald annealing pot.

rubber ring, giving an airtight joint between pot and cover right from the beginning. The cold-water trough is filled with water, and the pot placed in the furnace. Owing to expansion due to rise in temperature and to the vaporisation of the oil and grease on the material, the major portion of the air is forced out through the valve. The oxygen remaining in the air is used up in burning the oil and grease, so that long before the oxidation temperature of the charge is reached, the pot is wholly free from oxygen. Towards the end of the process the pressure in the pot falls, and the valve then closes automatically. When the required annealing temperature has been reached, the pot is hoisted out of the furnace by means of the crane and placed in the cooling pit, where it cools off in from 12 to 20 hours. No air enters the pot during cooling, and a vacuum of up to 400 mm. mercury can be obtained. The valve is opened

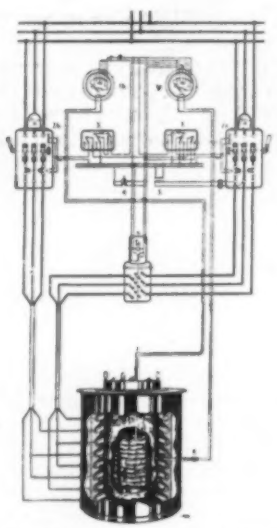
when cooling is complete—*i.e.*, when the requisite temperature for bright, blue, or black anneal, according to the finish desired, has been reached. The charge is now withdrawn, the plate lowered to the floor, and the tie-rods disconnected, and straightway fixed to another plate, which has previously been loaded with a charge ready for the furnace.

Any metal can be bri ht-annealed in the Grünewald pot. When metal which oxidises at a very low temperature is being handled, it is necessary to remove the whole of the oxygen from the pot before this temperature is reached, and the simplest method of doing this is to put a little red-hot charcoal in the pot before closing it.

The plant may be so arranged that the pots which are cooling are utilised for the preheating of freshly charged pots, the current thus saved amounting to about 40%. The number of pots which can be placed in the cooling pit varies with the rate of cooling, which is conditioned by the charge. The necessary draught may be obtained naturally by connecting the pit to a chimney, or artificially by means of a fan. In the latter case the draught can, of course, be varied at will, and it is also possible in winter to use the hot air for heating purposes.

An essential advantage is the placing of the furnace in the same room as the rolling plant. In comparison with the older plants, in which rolls and annealing plants occupy separate rooms, this arrangement considerably reduces transport costs. It is obvious that this is only possible where electrically-heated furnaces are used, which is also the only case where the advantages of the Grünewald annealing pot can be fully realised.

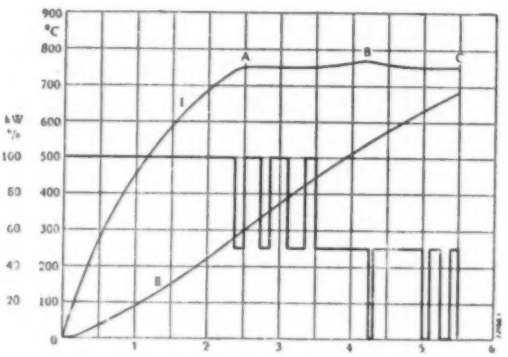
The Brown Boverie furnace, which is specially built for this pot, is distinguished by its exceedingly low current consumption and excellent temperature control. The



1a. Regulator and indicator for temperature of exterior of annealing pot.
1b. Regulator and indicator for temperature inside pot.
2a, 2b. Main switches.
3. Intermediate relays.
4. Push-button switch.
5. Voltage transformer.
6. Automatic switch.
7. Pyrometer measuring temperature in annealing pot.
8. Pyrometer outside pot.
9. Annealing furnace.

Fig. 2.—Diagrammatic arrangement of a Brown Boverie annealing-furnace layout.

heating elements are in two or three sets according to the size of the furnace, and the supply of current is controlled by temperature regulators and automatic switches, so that the necessary temperature is obtained in the shortest possible time, and is not exceeded in any part of the furnace. Fig. 2 shows the main connections to a furnace with two sets of heating elements. The one set is connected to the 500-volt mains through the main switch 2a and the automatic interrupter 6, the other set being connected direct through the main switch 2b. The two temperature regulators, 1a and 1b, which also indicate the temperature of the furnace, control the current consumption by means of the relays 3 and the interrupter 6. The regulator 1a is actuated by the thermocouple 8, which measures the temperature on the outside of the pot. When the temperature to which the regulator is set by means of the three central contacts is reached, the power consumption of the furnace is regulated between 100 and 50% of its maximum value (point A, Fig. 3) by the automatic device 6. When the annealing process has progressed so far that 50% of the power is more than is required to maintain the desired temperature on the outside of the pot, the main switch is cut out by an intermediate relay (point B, Fig. 3), and from there on the power is regulated between 0 and 50% till the temperature of the charge reaches the desired limit



I.—Temperature of outer edge of annealing pot.
II.—Temperature in side annealing pot.
A-B. Power consumption between 50 and 100%.
B-C. Power consumption between 0 and 50%.
O-A. Full power consumption = 100%.
C. Annealing completed.

Fig. 3.—Temperature curves and power regulation for a charge of 2,000 kilogs.

at the point C. The main switch 2a is now cut out by the temperature regulator 1b, and the service men notified by means of a light signal or a bell. Thus, the annealing process requires no supervision: it is only necessary to charge the pots and to place them in, and lift them out of, the furnace and the cooling pit. Fig. 3 shows a typical chart for the annealing of a 2,000 kilog. charge of hoop iron, the charge not having been preheated. The heating elements were switched in and out entirely automatically with an accuracy of ±5° C. Throughout the process the furnace was perfectly regularly heated over its whole height and periphery.

Metal which has been uniformly and completely b.ight-annealed at the theoretically correct temperature can be further worked more easily and with greater exactitude, and only by this means can all the advantages of the newer rolling and drawing methods be fully realised and work in these sections carried out with the maximum economy.

Structural Castings for the New Cunarder.

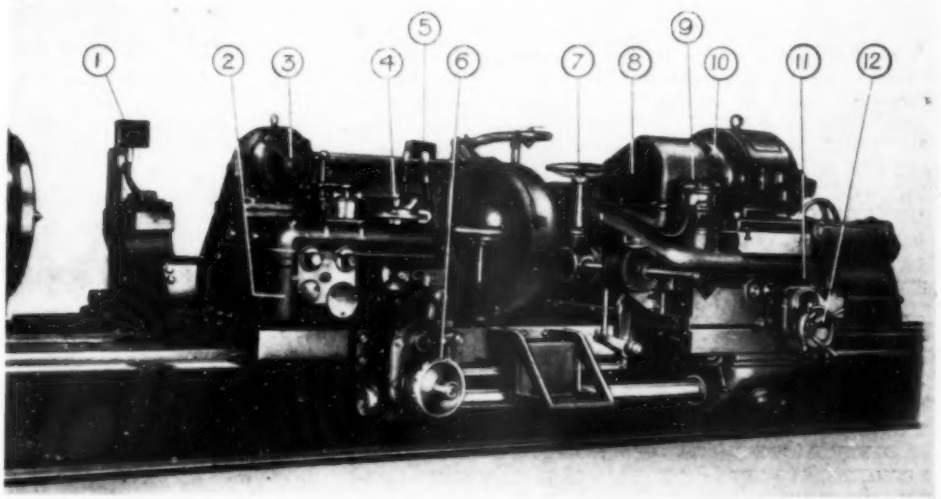
It has been officially announced that the contract for the huge structural castings for the new Cunard liner, which Messrs. John Brown and Co., Ltd., are to build at Clydebank, has been awarded to the Darlington Forge Co. This company have been responsible for the forgings and castings of many big liners, including the *Mauretania*, *Aquitania*, *Carmania*, *Olympic*, and *Brittanic*, but the castings for the new liner are to exceed in size and weight anything that has hitherto been made; a certain amount of shop changes and extensions will, therefore, have to be made before the work is commenced. The contract includes the castings for the stern frame, shaft-brackets, and rudder, and will necessitate the casting of some 800 tons of molten steel. The work will occupy eight or nine months, and the carrying of these castings to Glasgow will constitute a new record in heavy transport.

Recent Developments in Tools and Equipment

New Model Roll-grinding Machine.

THE demand for a high degree of accuracy in the products of the rolling mill is continually increasing, and in view of the constant need of cheapening production and the development of materials possessing increased physical properties, greater stress is being imposed upon the mills, and incidentally the rolls. The improvement in the production of rolls has been considerable during recent years, and it is now possible to meet the demands for greater accuracy in the production of sheet or plate, whether from hot or cold rolling. It is only as a result of developments in machine tools and measuring instruments involved in the production of rolls, that the requirements of the sheet-rolling mills have been supplied. Too often progress is retarded as a result of lack of development of a process in the line of production, but it is becoming increasingly recognised that, to be of any real value, progress must encompass all the processes leading to the finished product.

To secure accuracy in rolling-mill operations, much depends upon the accuracy of the rolls, for which the most important requirements are: True necks, true roll bodies, and accurate concavity or convexity of face to dimensions required. To obtain a high degree of accuracy much experimental work has been involved, and while progress in the development of the right type of machine for this purpose has been slow, the results now possible indicate the remarkable degree of success that has been achieved. One of the pioneer firms of this type of machinery is H. A. Waldrich, of Siegen, Germany, whose experience has enabled them to perfect a roll grinding machine of a very high order.



1. Fixed Steady.
2. Gearbox for longitudinal feed.
3. Motor for longitudinal feed.
4. Control wheel for longitudinal feed.
5. Hand lever for control.
6. Handwheel for adjusting concave or convex grinding.
7. Handwheel for accurate adjustment of grinding wheel by hand.
8. Gears for bringing grinding wheel automatically into action.
9. Auxiliary motor for rapid adjustment of grinding wheel.
10. Motor for grinding wheel.
11. Index dial for concave and convex grinding.
12. Handwheel for concave and convex adjustment.

Fig. 1.

This latest development embraces the results obtained from continual experiment and research, and fulfils the requirements of rolling mills. In its design and construction the firm has concentrated on accuracy in regard to operation, and stability of structure. The older design of this machine is well known, but the latest model, illustrations of which are shown in Fig. 1 and 2, has many important improvements. It has been found that inaccuracies are likely to occur at the roll necks, with the result that the whole roll is thrown out of truth. The first object in the design of the grinding machine is to overcome possible inaccuracies at the neck, and the results achieved have been such that rolls can now be ground to an accuracy of within 0·0002 in. without difficulty. To accomplish this, fixed steadies are incorporated in the machine. These fixed steadies are constructed with an opening on the side near the grinding wheel, so that the necks can be ground while they are running in the steadies. A further improvement in these steadies enables the steady-bearing blocks to be so adjusted that they are truly tangential to the roll-neck circumference: this ensures continuous accuracy in working. After the necks have been trued up in the grinding-machine steadies, the body of the roll is ground, and, as the roll remains in the fixed steadies during this operation, absolute accuracy is ensured. This grinding machine is so designed that neither tailstock nor headstock centres revolve, and when they have been accurately adjusted, their axis remains exact and fixed. Whatever size the roll may be, the necks are always ground true previous to grinding the body.

In the operation of grinding rolls concave or convex, difficulties are frequently experienced, because the degree of concavity or convexity varies with the length of the rolls and with the purpose for which they are used, whether for hot or cold rolling, or as polishing rolls. This operation was formerly accomplished by means of templates, or guides were shaped or adjusted. After much consideration and research it was decided to dispense entirely with templates and guide-bars in this roll-grinding machine. For this purpose a patent automatic device is incorporated in each size of machine, which is readily adjustable for all degrees of convexity or concavity within its range, and, whatever the length or diameter of the roll, this device enables it to be ground accurately concave or convex, and with any type of curve, *ie.*, arc of a circle sine line, parabola, irregular curves, etc. The accuracy of the motion is quite independent of the operator, and no inaccuracy can arise. The patent device elevates and depresses the intermediate section of the grinding-wheel carriage, turning it about a fixed point on its front side, so that the path of the grinding-wheel during its longitudinal motion follows a previously determined curve with regard to the axis of the roll. This new cambering device is driven by gear-wheels, which control the upward and downward motion of the intermediate section of the grinding-wheel carriage in relation to the longitudinal

motion. The degree of convexity or concavity relative to the length of the roll face is determined by the position of a division plate, which is operated by a hand-wheel, the relationship between the length of face and the degree of concavity or convexity being shown on the plate. This new cambering device is shown in Fig. 1.

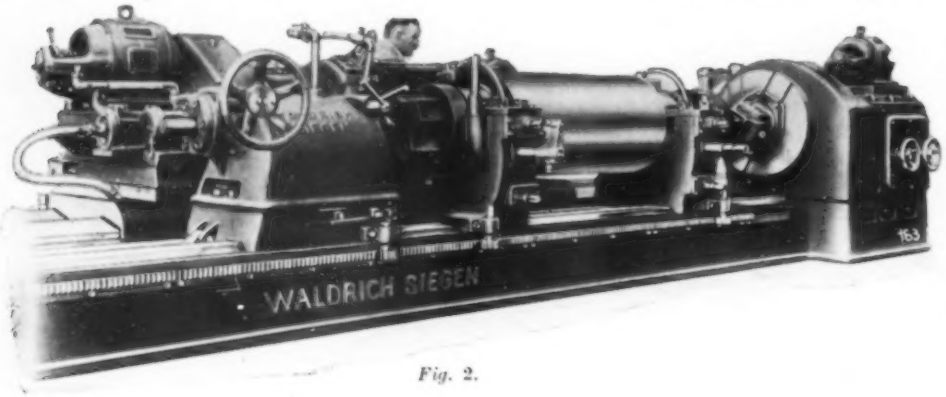


Fig. 2.

On the new model the wheel-head can easily be adjusted to suit various diameters of rolls, by means of a special motor mounted on the grinding slide ; the control is within easy access of the operator, and a push button system sets the upper part of the slide in motion. This differs from the older model, in which the operation was accomplished by turning a hand-wheel at the bottom of the slide, which necessitated the operator leaving his position.

These machines have generally been considered to be sturdily built, but owing to increasing demands on the power of the machine, it is now built on more powerful lines. Special attention has been given to distribution of the weight on the grinding carriage. The feed gearbox and the base for the wheel-head are symmetrically arranged, with the result that the load of the wheel-head carriage is equalised and decreases the wear on the guides of the carriage, which is an important factor in the maintenance of accuracy in the machine. The machine has been designed to accommodate any higher grade of grinding-wheels that may subsequently be devised, as it is so arranged that the motors can be changed and increased in power 100% without affecting its accuracy in operation.

There is a completeness about this machine that is altogether admirable, everything being included that is necessary for completely finishing rolls. It can be fitted with various devices, which include a special fitment for grinding the radii of the roll necks, for regrinding the dead centres, and for trueing the grinding stone and giving it a slightly crowned shape, when desired, for grinding a camber. Every effort has been made, as a result of long experience with roll-grinding machines and co-operation with users, to bring out a new machine in which everything likely to lead to unsatisfactory working is avoided. In its present form the machine provides an excellent example of the experience of the machine-tool designer, and illustrates the strides made in the progress of rigid machines to facilitate vibrationless grinding with a high output, factors which ensure accuracy together with low cost of production.

"Solidend" Tools.

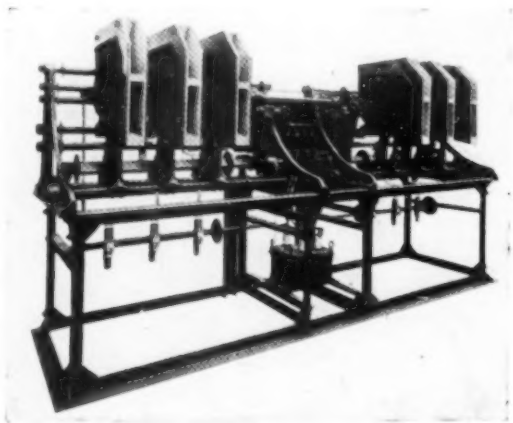
A FORM of tool has recently been marketed by Samue Osborn and Co., Ltd., which is claimed to be an important advance on any existing types of tipped tools. These tools consist of a solid piece of Osborn's S.O.B.V. cutting alloy butt-welded on a high-tensile steel shank. The welding is done by a special process, no cementation being used, but there is complete fusion of metals forming the weld, which as a result of tests has proved to be stronger than the steel itself.

These tools are claimed to have many advantages over ordinary tipped tools, and include a greater amount of high-speed steel, which allows for more grinding and increased life ; the solid end admits of heavier cutting ; the tool can be re-hardened, and, if necessary, re-forged without spoiling the weld ; the solid end carries the heat away readily, and there is no tip to work loose. In addition, it may be mentioned, that, while with ordinary tipped tools the mild steel base comes in contact with the emery wheel when grinding, and tends to glaze the stone, these new "Solidend" tools are so formed that no mild steel touches the grinding wheel, and the process of grinding is, therefore, perfectly safe.

These tools have been submitted to exhaustive tests, and although they cost a little more than the ordinary tipped kind, the reports of these tests indicate that the advantages outlined above more than compensate for the extra cost. The tools are obtainable in the usual shapes for turning, boring, planing, and slotting, or to special shapes desired.

High-tension Reversing Contactor for Rand Mines.

AN interesting item in a large electric winder equipment which has just been shipped to South Africa by the General Electric Co., Ltd., is the high-tension reversing contactor shown in the accompanying illustration. The rating of the contactor is 2,200 volts, 400 amps. ; but as the supply system is liable to voltage surges of considerable magnitude, the insulation is designed to withstand a high potential test of 30,000 volts.



High Tension Reversing Contractor.

It will be seen that a metal and micanite construction is used, both fixed and moving contacts being carried on substantial micanite-covered shoe-bars, on which ample surface clearance has been allowed. Each set of three moving contacts is operated by a 3-phase magnet, and the "forward" and "reverse" sets are interlocked both mechanically and electrically, so that the arc on the opening set is completely ruptured before the other set closes. The arc chutes have large laminated iron cheeks, and in order to secure a long and effective blow-out, tapering laminated ribs are fitted to distribute the flux over the whole area of the chute. It is interesting to note that the length of the wind is 3,150 ft., and the normal load 5 tons of rock, the accelerating horse-power peak being 2,500, with a winding time of 86 secs.

The Metallurgy of Bronze.

THE importance of the art of founding, particularly in regard to the compounding of metals, is diminishing year by year before the methodical application of science conducted by experts in each branch of the subject. These experts are applying the laws of chemistry, physics, and mechanics to metallurgical operations of all kinds. Many alloys in use to-day are modifications of alloys prepared as a result of experience, but by rule-of-thumb methods, before scientific knowledge of metals had developed to the extent at present recognised. Indeed, in many instances the compositions of certain alloys were regarded as secret processes upon the maintenance of which the reputation of many firms depended, and it was customary to observe the utmost caution in preserving these secrets. This is particularly true of the preparation of alloys in the brass foundry, and while the same method is still in operation in some foundries, it is gradually diminishing in the light of metallurgical progress. As a result of investigation and research, much useful information has been acquired which has materially assisted in placing the compounding of metals on a sounder and more scientific basis. These investigations, together with information derived from microscopical examination in conjunction with chemical analysis of the metal employed and the application of mechanical and physical tests, have established within reasonable limits the essential properties properly compounded alloys should possess. Although there are yet difficulties to be overcome, the results so far achieved, when applied in practice, have raised considerably the standard of production. But while scientific knowledge unfolds new theories, and both the student and metallurgist may readily grasp the underlying principles, there is a danger that the valuable detailed knowledge associated with the development of the new theories may be neglected. It is undoubtedly true that ultimately the practical application of general principles rests on the understanding of specialised detail, and Mr. Dews has done a very useful service to metallurgists and non-ferrous foundrymen in correlating the metallurgical data accumulated about bronze alloys. In addition to the essential compounding of these alloys and the complexities experienced in their production, the author has assembled the known facts with careful regard to their practical application, and has incorporated his own extensive experience in this specialised section of non-ferrous metallurgy.

The most critical consideration has been given to those scientific researches which have had, or are likely to have, a distinct bearing on practice, and the author rightly insists upon the experimental proof of a theory in order that the real practical value of scientific methods can be adequately appreciated. To ensure successful results from castings in the various bronzes, it is essential to have skilfully compounded alloys with strict supervision of temperature and furnace conditions, but while these can be controlled within reasonable limits, the cooling conditions introduce variables which add to the complexities of production.

An interesting feature about this work is that in addition to the reliable information it contains on the subject of bronzes, the author indicates what there is he wants to know and how difficult it is to obtain the new knowledge he desires. In this way he focuses attention upon new avenues for further research and investigation. The author has been concise, yet comprehensive, in his treatment of the subject, and he is to be congratulated on the admirable manner in which the valuable information is presented. The micro-photographs and diagrams are well produced, and a very complete index is appended. This work can be confidently recommended to students, metallurgists, and foundrymen associated with this important section of the non-ferrous industry as a work of outstanding quality and one which cannot profitably be omitted from works of reference on non-ferrous metallurgy. By H. C. Dews. Published by Sir Isaac Pitman and Son, Ltd., Parker Street, Kingsway, W.C. 2. Price 12s. 6d. net. J. E.

Metallurgy of White-metal Scrap and Residues

THE enormously increased production and consumption of metals within the last twenty years, and the correspondingly rapid accumulation of metallurgical and industrial wastes, has rendered the efficient recovery of these products an important economic necessity. The development of this branch of metallurgical practice presents a problem which, in view of the variables in the processes involved, and the ever-changing industrial conditions, is hardly equalled by the technical difficulties encountered by any related industry. In view of the rapidly growing importance of the scrap and residue-treating industries, it is rather remarkable that little or no attention has been given to the subject in metallurgical literature. Their importance is convincingly reflected in the increase of volume and value of non-ferrous scrap and residues handled. From 1918 to 1925, for instance, the production of secondary lead, zinc, aluminium, and copper increased by 175, 125, 190, and 60% respectively, while the respective figure for tin, 11%, is by far the lowest for the commoner metals.

The problems facing the non-ferrous scrap and residue industries are not limited to the rational evaluation of scrap and residues alone, but include the elimination of unnecessary waste in production, distribution, and consumption as well. Increasing attention is being directed to waste in production, and a movement has now become general for its elimination. In view of the wide variety of this work and the numerous difficulties to be overcome, progress in simplification and standardisation is not as rapid as could be desired ; but much has been accomplished, particularly in the United States of America, and there can be no doubt that by uniting the efforts of all progressive elements directed towards this end, success will gradually be achieved in the wide field embraced. Ultimately, the policies adopted by various interested societies and authorities will drift into uniform channels, the experience of one group serving to determine or modify the policies of others ; but this comprehensive publication on the metallurgical treatment of scrap and residues will assist very considerably in forming a basis for a progressive policy.

The author does not claim it as an encyclopædia on the subject, but he has, nevertheless, given very careful attention to details in the various processes involved, and for a first publication of this kind it contains a remarkable amount of information. In addition to the elementary, as well as important, facts directly and indirectly related to the metallurgical treatment of white-metal wastes, including zinc and aluminium materials, particular attention has been paid to the condition and requirements of small and medium-sized plants, operating independently or in connection with large manufacturing or engineering concerns working up their own scrap and residues ; allied subjects, such as engineering construction matters, mechanical apparatus used for transportation, briquetting, blast-furnace operation, etc., have been treated generally in a descriptive manner.

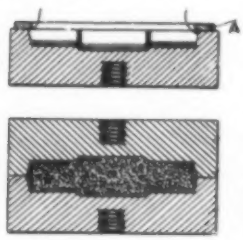
The industry associated with the reclamation of waste metals and alloys bristles with peculiarities, and the author makes the plea that rule-of-thumb methods should be supplanted by scientific and rational operation, and the ancient customs still prevailing throughout the non-ferrous scrap and residue-dealing trade should be abandoned in favour of modern and efficient business methods. The general advancement in the older and more advanced industries has been directly due to the degree of co-operation between its individual units, and there appears to be no reason why the scrap-metal industry should not realise and apply this principle as well. All interested in this industry will find an immense amount of valuable information in this comprehensive work. By Edmund Richard Thews. Published by Messrs. Chapman and Hall, 11, Henrietta Street, Covent Garden, London, W.C. 2. Price 25s. net.

Some Recent Inventions.

PRODUCING CORES BY AN IMPROVED PROCESS.

IN connection with the production of cores for use in repetition casting, the cores either involve the use of skilled labour, with a consequent increase in the cost of the cores, or are produced by machines. When machines are used, the cores are either of a fragile nature or require for their production the provision of relatively expensive multiple core boxes. An improved process has for its object the provision of a machine for forming the cores, by which strong and durable cores may be produced readily and speedily and without involving the use of expensive multiple core-boxes.

The process consists in the employment of a pair of oppositely disposed rotatable members provided with a plurality of faces to each of which is attached a section of a wide variety of two part core-boxes. One member carries one set of sections, and the other the complementary sections. Each set is filled separately with a surplus layer of sand, for which a removable template is adopted, and the rotating members bring the respective pairs together when pressure is applied to compress the sand into the core shape.



Figs. 1 and 2.

Referring first to Figs. 1 and 2, the cores are formed in a single core-box comprising two sections. Adapted to be disposed on the face of the outer portion of one of the core-box sections, during the process of the formation of a core, is a plate A of skeleton formation and of a shape corresponding to the profile of the core to be produced. The core-box sections are filled with sand and binding material and the surplus struck off. The removal of the template leaves a surplus layer of sand above the normal face of one core-box section. The two sections of the core-box are then brought together and pressure applied until the edges of the respective sections abut one another (see Fig. 2).

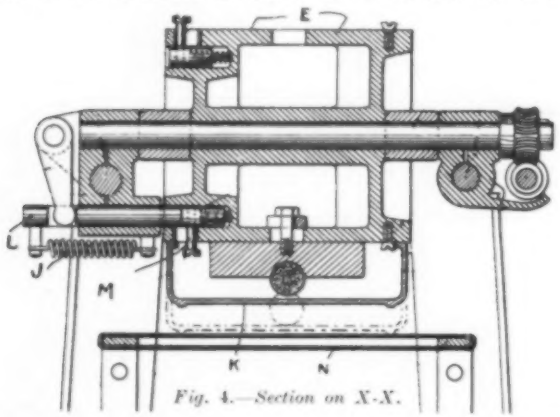


Fig. 4.—Section on X-X.

The machinery for carrying the process into effect is illustrated in Figs. 3 and 4. It comprises a base-plate at each end of which are standards which support a couple of cylindrical bars B B, which constitute slideways for bearers C C. These bearers are provided with knurled nuts D D, which engage the bars at the ends in such a way that the bearers can be locked in a desired position. Each pair of bearers carries a shaft on which is mounted a rotatable body member having four symmetrically disposed faces E. Rockably mounted on a shaft F are the ends of a pair of toggle links, the other ends being secured to a spindle carried by a piston rod operating in a compressed-air cylinder. The other pair of links G of the toggle linkage are rockably mounted on a spindle which is supported in bearings carried by the standard. Each face of the body members E is adapted to carry a core-box section. The spindles carrying these body members have worm-wheels keyed at one end, which mesh with worm-wheels on a rotatable longitudinally disposed and slidable shaft, so that when the shaft is rotated the body members, carrying the core-box sections, rotate in opposite directions. The handle H is then released so that when the bolts come opposite the next holes O, they are forced in by the springs J, valves being reversed to cause the toggle G to be straightened and the core-boxes to be forced together. The operation is then repeated on the next boxes, and as the boxes containing the compressed core separate, a tray K is attached to the member E over the box, which retains the core N by studs, so that at the next rotation the core falls into the tray. When the bolt L engages the hole O the stud M, which is carried by a spring plunger, is disengaged from the tray, which falls on to a resilient support N.

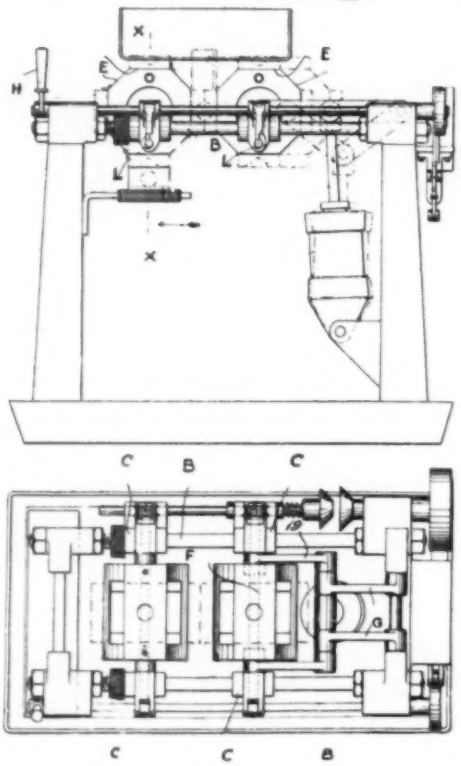


Fig. 3.

331,656. CHARLES H. TAYLOR, Stourbridge, Worcester, patentee. Messrs. Shaw, Bowker and Folkes, agents, Temple Row, Birmingham. July 10, 1930.

PREPARATION OF ALUMINIUM OXIDE.

ALUMINIUM oxide, practically free from impurities, such as iron, silica, and titanium, can be prepared by fusing aluminous materials, like calcined bauxite, with carbon, iron, and aluminium sulphide, this latter not exceeding 3% of the aluminous product. The aluminium sulphide is preferably produced in the furnace by the addition of a sulphide of iron, iron pyrites being suitable. The operation should be conducted in a carbon-lined tapping furnace, and the charge tapped into a ladle, where metallic iron separates from the aluminous product. In addition, some aluminium carbide, a suboxide of aluminium, metallic aluminium, and ferro-aluminium, are produced. The non-metallic part, consisting of small crystals of alumina separated by the above-mentioned reduction products and aluminium sulphide, is disintegrated, preferably by saturated steam, but acid, alkali, chlorine, hot or cold water, or superheated steam may be employed.

332,902. W. W. TRIGGS, 57, Lincoln's Inn Fields, London. (Norton Co.; Worcester, Massachusetts, U.S.A.)

Business Notes and News

Oxy-acetylene Amalgamation.

The British Oxygen Co. and Allen-Liversidge, Ltd., two companies which have worked in close co-operation during recent years, have now decided that the full benefit of co-ordination can only be achieved by a complete amalgamation.

Both companies are manufacturers of oxy-acetylene welding and cutting appliances; but the production of dissolved acetylene has hitherto been confined to Allen-Liversidge, Ltd., while the development of the oxygen industry in this country has been due to the British Oxygen Co.

The progress which has taken place during the last 25 years in welding and cutting has created an enormous demand for both acetylene and oxygen. Experience has proved that it is desirable to keep plants for the production of these two gases in separate factories, reasonably adjacent, rather than in adjoining premises. Since 1910 both companies have co-operated on friendly terms, with the result that the acetylene factories of Messrs. Allen-Liversidge have been installed, in the majority of cases, in the vicinity of the oxygen-producing factories of the British Oxygen Co.

An agreement has now been drawn up between the two companies, full details of which have been issued in circular letters sent out by both companies to their shareholders. Careful consideration has been given to the financial aspects of this agreement, and the directors think that the terms are beneficial to the shareholders of each company. In order that shareholders might have full information, a meeting took place at Caxton Hall on December 2 for the shareholders of Allen-Liversidge, while a meeting is to be held on Dec. 18 for those associated with the British Oxygen Co.

Competition for New Applications of Aluminium.

A competition, designed to encourage development in the aluminium industry, is to be held by the International Aluminium Bureau. It will be open from January 1 to April 1, 1931, to inventors of any nationality, and prizes will be awarded for the best suggestions for new applications of aluminium and its alloys, or for improvements in its manipulation. The competition will be divided into two sections: Section A, dealing with proposals relating to the manufacture of an article, or machine, or part of a machine, in aluminium or aluminium alloy; and Section B, dealing with proposals for improvements in the methods of working or using of the metal or its alloys. Prizes of 25,000 francs (French) are offered for the best entry in each section, and a special prize of 50,000 francs for the author of a suggestion of exceptional interest or value under either section. Further particulars regarding the rules and conditions of this competition may be obtained on application to the British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4.

Modern Ship Design.

"What is needed is an organisation which, by research, experiment, and invention, will effect a material and comprehensive improvement in ship design, not necessarily by radical changes, but by cumulative improvements in detail," said Mr. John Tutin, in a paper read to the Institute of Marine Engineers on December 9. He said that in considering the problem of the more efficient ship, it was necessary to form a mental picture of first cost and operating cost. If the shipbuilder was not also an engine-builder, about two-thirds of the cost of the ship would go to the machinery manufacturer, and therefore the shipbuilder could only economise on one-third of the total cost. Operating costs varied tremendously with every type of ship, but serious losses occurred at every stage of the process of turning fuel heat energy into useful work.

As regards improvements in propulsion methods, developments had been made in different countries, but the routine testing of normal hulls occupied experiment tanks so fully that there was little time for research work on unconventional designs; there remained great room for improvement in the methods of coating under-water hulls, and in bilge keel and bow design.

If there was to be a further demand for passenger vessels, they must be made vastly more comfortable where needed, and less luxurious where luxury was superfluous. The ideal to aim at, however, was immunity from vibration; and there was no reason why that should not be attained with the aid of electrical synchronisation of engines. A tramp steamer need not be attractive, but it must be efficient. A passenger vessel must be attractive to its passengers, and must partially sacrifice efficiency for speed.

"Quite frequently," concluded Mr. Tutin, "supply creates demand, and the development of new types of hull and machinery may provide a solution for an unexploited service."

Building Extensions.

In these times of industrial depression, there are few firms confident enough to undertake large extensions to their premises. In this respect, Messrs. G. A. Harvey, Ltd., of London, are to be congratulated. This well-known firm of sheet-metal and steel-plate workers have seized the opportunity to think out and organise for the trade expansion that is bound to come, and are adding to their works, which already cover 27 acres at Woolwich Road, London. The new building, which will be 300 ft. long, 250 ft. wide and 65 ft. high, is to be constructed for their steel plate construction and steel furniture and equipment departments, which have both developed during the last two years. Increased facilities will be afforded for the production of every description of industrial plant.

Unsatisfactory Electric Tariffs.

The extraordinary diversity of the tariffs employed in connection with the public supply of electricity was referred to by Mr. E. G. Phillips, M.I.E.E., M.I.Mech.E., at a meeting of the Institution of Heating and Ventilating Engineers, when discussing the cost of operating industrial and private electric generating sets compared with public supply. His contention was that the supply company's engineer was usually too scientific to be commercial. It was quite easy to understand the basis of such complicated tariffs; technically they were correct, and could be justified, especially from the supply authorities' point of view, but it was neither desirable nor commercially sound for the supplier or the customer to be unable to estimate the cost of the commodity on offer. Mr. Phillips urged the supply authorities to "commercialise" their present "scientific" tariffs, or at best make an honest endeavour to educate the prospective consumer by giving one or two practical examples on their literature.

Royal Aeronautical Society Council Dinner.

A dinner was given recently to Colonel the Master of Sempill, A.F.C., F.R.Ae.S., Past President of the Royal Aeronautical Society, by those members of Council who had served under him during his period of office from 1926-1930. The dinner was held at the Army and Navy Club in Pall Mall, and was presided over by Mr. C. R. Fairey, M.B.E., F.R.Ae.S., President of the Society.

As is well known during the years that Colonel the Master of Sempill has been President, the growth of the Society has been most remarkable, and the Council unanimously decided to pay him the signal honour of a special dinner on his retirement, and at the same time to give him a permanent souvenir of their appreciation of his untiring energy and devoted services on behalf of the Society. Colonel the Master of Sempill was presented with a case of cutlery suitably inscribed and engraved. During the evening many messages were read expressing regret at the retirement of the Master of Sempill. They included the messages from the two Patrons of the Society, H.R.H. the Prince of Wales and H.R.H. the Duke of York, and also from members of the Society, including Sir Joseph Petavel, Mr. Orville Wright, Lord Wakefield, Major Lester Gardner, Mr. Edward Warner, and many others.

Weston Fellowship in Electrochemistry.

The Fellowship ($1,000) is open to candidates who have completed an undergraduate course in some college, university, or technical institution, and have received a degree of such institution. The candidates must possess marked capacity in carrying out research in electrochemistry, and must be under the age of 30 years at the time of the award.

The award will be made without distinction on account of sex, citizenship, race, or residence, and will be for a term of one year; but the Board of Directors shall have the option in its discretion of continuing the award to the same Fellow. The successful candidate may carry out the research in electrochemistry at any institution of learning approved of by the Board of Directors of the Society.

Applications for the Fellowship for the academic year, October 1, 1931, to June 1, 1932, must be received by the Secretary of the Society *before March* 1, 1931. Application forms, together with further particulars, are obtainable from Colin G. Fink, Secretary, The Electrochemical Society, Columbia University, New York City.

Business Notes and News—continued.

Lord Furness on the Evils of Dumping.

Lord Furness, presiding at the annual meeting of shareholders of the South Durham Steel and Iron Co., Ltd., held at Middlesbrough recently, stated that in the early part of this year certain directors, under the direction of their managing director, had conversations with their neighbours, Messrs. Dorman, Long and Co., Ltd., with the object of seeing whether closer working arrangements would be to their mutual advantage. The great fall in the demand for all steel products, which began in the early part of this year, showed that under those conditions there was nothing to be gained from any of the suggestions that had been discussed, and he had come to the conclusion that until this country was freed from dumping, no advantage could be obtained from so-called rationalisation, which involved further large capital expenditure. It was probable that the compact units of moderate size, such as theirs, improved as opportunity occurred, under present conditions would cope with the situation more satisfactorily to its shareholders.

He could not make any hopeful forecast for the immediate future. At present the demand was very restricted, and their works at West Hartlepool were only partially running. It was impossible to foretell how long the world depression would last, but they could only hope a sign of improvement would not be too long delayed.

Baths for Iron and Steel Workers.

The Industrial Health Research Board are anxious that workers in the iron and steel industry, as well as miners, should have baths at their disposal when they finish work each day. With the object of interesting the directors of these industries and investigators into similar problems, they have published a report dealing with the atmospheric conditions found in pithead baths by Dr. H. M. Vernon and Dr. T. Bedford. This report states that in a new design adopted for baths there were separate sections for pit clothes and clean clothes, so that clean clothes and clean men were separated from any places in the building where coal dust collected. Four experimental stations had been erected, and 42 other installations, with modifications, were now in course of erection.

Though the design of the best form of pithead baths, having regard to the provision of comfortable conditions for the men while changing, to adequacy in the drying of their pit clothes, and to cost of erection, had not yet been attained, the two-room system was a great improvement on the one-room system, in which clothes, both clean and dirty, were suspended by ropes and chains. Still, it was more expensive, and if, in course of time, baths and changing rooms were to be erected for the men employed in other hot and heavy industries, such as the iron, steel, and tinplate trades, as well as for coal miners, it might well be that the question of expense would be held to exclude the adoption of two-room baths. In such a case it was to be hoped that the present one-room suspension system would be combined with the locker system, by giving each man a locker for his clean clothes as well as a suspension hook for his pit clothes. This plan had already been adopted at one or two baths.

Another variation would be to have two changing rooms, but to install the overhead suspension system in the pit-clothes sections, and retain the lockers in the clean-clothes sections.

Stainless Steel for the Home.

The value of stainless steel for many purposes has been appreciated for a long time, but up to the present it has not been introduced in the home to the extent that is desirable. During the past few years, however, a number of firms have been experimenting in the production of a stainless steel, which would be sufficiently malleable for the manufacture of articles in everyday use and which are at present made in brass, copper, and chromium-plated metals. It is claimed such a steel has now been produced which is not only ductile, but is much more durable than other metals now used for this purpose.

The steelmakers who are behind this development had in mind, when they began their research work, the extraordinary success of stainless steel when, twelve years ago, it was used for the manufacture of cutlery, and they are certain that the new metal, when applied to the production of other household articles, will prove as advantageous as the cutlery and become a boon in every household in the country.

Transporting Machinery by Rail.

The London and North Eastern Railway Company are to be congratulated on the arrangements made for the successful transportation of machinery from Messrs. Parson's works at Newcastle. The consignment of machinery is the second to be sent to Holland to the order of the Provencial Electriciteitsbedrijf Van Nord for the new power station at Velseo, Holland. The machinery consisted of two Parson's 24,000 k.w. turbo alternators. A special train comprising 24 wagons was loaded up at the works. One of these was a well trolley wagon, weighing nearly 39 tons, conveying a stator of 65 tons, making a single wagon load of 104 tons, the heaviest ever loaded on the train ferry. The next in weight was an armour-plate wagon, of 31½ tons, carrying a piece of machinery weighing 37½ tons, making 69 tons in all.

Some of the machinery was so large as to overhang the wagons considerably, and it was necessary to keep the adjoining track clear throughout the journey from Newcastle to Harwich. This journey required a good deal of preparation by the London and North Eastern Railway Co., for, at some places, it was necessary to lower the lines to enable the train to pass under bridges. At Chappel the line was slewed and smoke-plates under the bridge were removed. At Sudbury it was not only necessary to remove the smoke-plates, but also to run the train on the wrong line, as the load overhung so much that it might have hit the side of the bridge. The line was lowered at a bridge near Shelford. At Haxey, near Doncaster, the train was run right across all the lines to the down line on the far side to remove the danger to passengers in passing trains.

The London and North Eastern Railway sent a wagon-wright with the train to facilitate the unloading of the machinery in Holland.

Gold Mining in Wales too Speculative.

The report of Professor Henry Louis regarding the possibilities of gold mining in Merionethshire does not indicate a probable development of this industry. Careful study of all the facts available concerning the Merionethshire gold belt has led him to exactly the same conclusion as appears to have been arrived at by all the other authorities who have studied this property. The gold is found in very occasional rich patches, which means that a large amount of development and cost would be incurred in the hope of finding one of these rich patches, as there is no indication of where these rich patches are likely to be found.

In the opinion of Professor Louis, there is very little chance of these mines being developed in such a way as to make them of any material value in regard to giving employment, and he could not recommend the expenditure of public money on such a speculative undertaking as gold mining in Wales has proved itself to be. That gold exists in these properties there can be no doubt, but it has not hitherto been found sufficiently evenly distributed to enable a permanent industry to be built up.

Carnforth Blast Furnaces Acquired.

Messrs. Thomas W. Ward, of Sheffield, has acquired the works of the Carnforth Hematite Iron Co., Ltd., which have been on the market for some time. These works, which were reorganised in 1915, are situated near Carnforth Station, and comprise three blast furnaces and appropriate plant, together with limestone quarries and about eight miles of railway. The capacity of each of the blast furnaces is about 1,500 tons of hematite pig iron per week. It will be some time before these furnaces can be started, but there will be much gratification in the Carnforth district that the works are again to be reorganised and operated.

Successful Tests of All-Metal Flying Boat.

Claimed to be the largest and fastest all-metal military monoplane flying boat built in this country, the *Sydney*, was launched from the Blackburn Aircraft Factory at Brough, near Hull, recently. She was immediately subjected to final tests and responded to all demands satisfactorily.

Designed by Major J. H. Rennie, the machine is the first all-metal monoplane flying boat built in this country for the Air Ministry. It has engines of a total of 1,500 h.p., which are capable of developing a speed of over 120 miles per hour. It has an effective range of over 1,000 miles. The hull is 65 ft. long, and the wings from tip to tip have a span of 100 ft. The flying boat weighs about 10 tons, and has accommodation for 16 men.

Some Contracts.

Frederick Smith and Co., of Salford, have obtained a contract from New Zealand for the supply of about 400 miles of bare hard-drawn H.C. copper strand, for overhead electric power transmission. The strand, which will weigh more than 500 tons, will be manufactured at the Salford works.

The Mersey Docks and Harbour Board have accepted the tender of Dorman Long and Co., Ltd., of Middlesbrough and London, for the erection of three rolling bascule bridges at Liverpool, the inclusive price being £96,969. All the steel employed will be of British manufacture from the Middlesbrough works, and work will be started on these bridges at once.

Further orders in connection with the new Dunston-on-Tyne "B" Power Station, have been placed by the Newcastle Electric Supply Co., Ltd. The contract for boiler-house and engine-room steel-frame buildings has been awarded to Messrs. Dorman Long and Co., Ltd., the value of the contract being about £129,000. In addition an order for two overhead electric travelling cranes has been given to Messrs. Joseph Booth Bros., Ltd., of Leeds, the value of the contract being about £5,500. Complete circulating water pump-house equipment will be supplied by Messrs. Drysdale and Co., Ltd., of Glasgow, at a cost of about £12,000.

Messrs. Dorman Long and Co., Ltd., have also secured the contract for the building of a new bridge at Rhyl at an inclusive cost of £66,000.

The Woodall-Duckham Co. have received an order from the South African Iron and Steel Corporation for a large installation of Becker coke-ovens for their new Pretoria works. The contract includes coal-handling, storage, crushing, and mixing plant; regenerative and combination type coke-ovens, coke-screening plant, and complete by-product plant for the recovery of ammonia, motor fuel, and tar products. The coking plant will produce coke for use in blast furnaces, the ovens being fired by blast-furnace gas.

The following contracts are among those recently placed by the Great Western Railway Co.:—108 1½—2-ton goods chassis, Dennis Bros., Guildford; reconstruction of the Eign Bridge over the River Wye, Geo. Palmer, Neath; reinforced concrete work at Alexandra Docks, Newport, Lotz and Kier, Stoke-on-Trent; 18 35—40-cwt. Morris vans, The Morris Garages, Ltd., Oxford; electrically driven centrifugal pumping plant for service at South Dock Basin, Swansea, Gwynnes Pumps, Ltd., London; electric cranes, Clyde Crane and Engineering Co., Mossend, Lanarkshire; 6 petrol-driven platform trucks, Douglas Motors, Ltd., Bristol; 6-ton hydraulic jib crane, Hollings and Guest, Ltd., Birmingham; element for ammonia condenser for cold stores, Farrington Works and H. Pontifer, Ltd., London; and a new twin-screw passenger tender for service at Plymouth, Earle's Shipbuilding Co., Ltd., of Hull.

International Combustion, Ltd., London, have been awarded a contract for the supply of new boiler plant in connection with the installation of new electrical generating plant at the Congella Power Station at Durban. The equipment comprises two combustion steam generators, complete with Lopulco pulverised-fuel-firing equipment.

The General Electric Co., Ltd., have been awarded two important orders, one for some three hundred heavy traction motors for the new London Underground Railway rolling stock, and the other for the complete electrical equipment of 61 new coaches now being built for the Metropolitan Railway, London. The orders total £250,000, and the equipment will be manufactured throughout at the company's works at Witton, Birmingham.

In the face of severe foreign competition the Fairey Aviation Co. have received a contract from the Belgian Government for the equipment of the Belgian Air Force with Firefly II. single-seated biplane fighters, the fastest of their kind in the world. This is the third contract the Fairey Co. have made with a foreign Government this year.

Messrs. Herbert Morris, Ltd., Loughborough, have secured a £10,000 contract for the supply of new foundry conveying plant for the Austin Motor Co., Birmingham.

Government contracts recently announced include the following:—

Admiralty: Doors, condensers, cast steel, Thomas Firth, and Sons, Ltd., Sheffield; plate (electro), Gladwin, Ltd., Sheffield; reservoirs firing, the Chesterfield Tube Co., Ltd., Chesterfield.

War Office: Gun billets, John Brown and Co., Ltd., steel (round), English Steel Corporation, Ltd., Sheffield; steel (medium tensile), United Strip and Bar Mill, Ltd., Sheffield.

Post Office: Ducts, Hepworth Iron Co., Ltd., Sheffield; telephone exchange equipment, D. P. Battery Co., Ltd., Bakewell, for batteries.

The Hawker Engineering Co. have received an order for the supply of between 225 and 250 aeroplanes to the Royal Air Force. The machines are to be Hawker Furies, which are considered to be the fastest fighting planes in the world. The bulk of the order, which will amount to more than £500,000, will be delivered during 1931, but only a few extra men will be employed, as the factory is equipped to cope with the work.

The following contracts have recently been received by the Metropolitan-Cammell Carriage, Wagon and Finance Co., Ltd., of Saltley, Birmingham:—From Assam-Bengal Railway, 15 underframes for 4-wheeled goods wagons; Bengal and North-Western Railway, 30 bogie carriage underframes; Rhodesia Railways, Ltd., two 80,000-lb.-capacity bogie well wagons; London Electric Railways, six 30-ton bogie flat wagons and one 20-ton bogie rail wagon. Gold Coast Railway, two first-class bogie carriages.

Crossley Motors, Ltd., Manchester, have received another repeat order for six-wheeled vehicles for the mechanisation of the King's African Rifles stationed at Kenya. This is the fourth repeat order, and makes a total of 26 20-60 h.p. Crossleys supplied for the King's African Rifles.

Harland and Wolff, Ltd., have received orders from the Government for four Royal Air Force motor-boats, three pinnaces, and a 200-ton lighter. The motor-boats and pinnaces are to be built at Liverpool, and the lighter at London.

J. I. Thornycroft and Co., London, have received an order from the Central Uruguay Railway for eight 3½-ton six-wheeled chassis with six-cylinder engines, eight 3-ton-type trailer chassis, and four 3-ton type.

The Horsley Bridge and Engineering Co., of Birmingham, have started work on the erection of a new swing bridge at the entrance to the Bute West Dock at Cardiff.

The Buenos Ayres Great Southern Railway have placed an order with the English Electric Co., Preston, Lancs., for the electrical equipment of their new Diesel electric rolling stock. This rolling stock is being built by Sir W. G. Armstrong, Whitworth and Co., who have also undertaken the supply of £6,000 worth of pig iron for the same railway.

The English Electric Co. have also been awarded a contract by the Liverpool Corporation for the supply of 12 pairs of equal-wheel tramcar trucks. The trucks will be complete with motors, and will be equipped with foot-operated electro-pneumatic control.

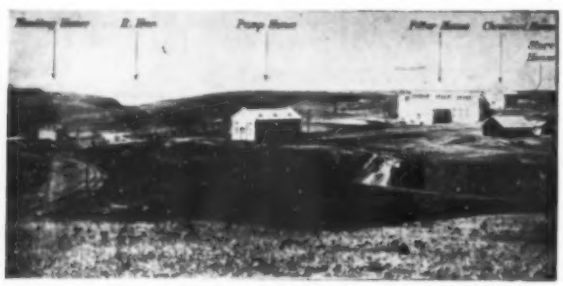
Following the suspension of work on the Assuan Dam on the Nile in September last, when the original contractors were faced with serious difficulties, the Council of Ministers has decided to award the contract for continuation of the work to Messrs. Topham, Jones and Railton. It is understood that the contract price is about £2,152,000, allowing for plant and materials already on the spot. Messrs. Topham, Jones and Railton were third on the list of original tenders.

The London and North Eastern Railway has accepted the tender of Sir Robert McAlpine and Sons for the construction of a bridge to carry the L.N.E.R. main line over the north circular road at Bounds Green Road, North London. The accepted tender for this contract amounts to £92,926.

RAPID GRAVITY FILTRATION PLANT FOR WATER SUPPLY.

ONE of the most remarkable industrial centres of the world at the present time, alike as regards iron and steel works, mines, coke-oven plants, railways, power stations, docks and harbours, low-temperature carbonisation plant for shale, and other activities, is South Manchuria, all based on the Fushun Colliery. Of great interest in this connection is a rapid water-filtration plant that has been installed, indicating also that town's supply methods for dealing with the whole water supply, as distinct from boilers and special applications only, are commencing to be used in industry.

The site of the Fushun Colliery, the largest open-cut mine in the world, operating a special variety of hard sub-bituminous coal, is the Province of Fengtien, South Manchuria, about 22 miles east of Mukden. Over 60,000 people are now employed at Fushun—Japanese, Chinese, and Koreans,—and the old and small town of Fushun has already been swallowed up by the open-cut mining operations. For this reason a complete new town on the most modern lines has been built to accommodate 90,000 people, and it is largely in this connection, as well as the colliery and accessory equipment, that a subsidiary company, the Fushun Waterworks, is operating.



The filtration plant was supplied to them in 1922 by the Paterson Engineering Co., Ltd., of London, although information on the subject has only recently been made available, and consists of a rapid gravity filtration equipment to deal with 4,320,000 gals. of water per 24 hours, and capable of extension by a further 1,500,000 gals. in the immediate future. There is provided chemical reagent gear for the continuous addition of alumina and lime to the raw water, as controlled automatically by the flow of the water, using a Venturi tube device, a reaction and precipitation tank to mix the reagents with the raw water, and six standard "Paterson" compressed-air-cleaned rapid gravity sandfilters, each 23 ft. × 12 ft.

The compressed air for cleaning the same—that is, by agitation for a very brief period to disentangle the separated impurities, followed by momentary reversal of the flow of the water—is provided by an electrically driven air compressor with air-storage reservoir, the water being driven from the high-pressure main leading to the Rikaka Reservoir.

This standard principle of rapid sand filtration as used in town's water supply, with coagulent treatment, is necessary to remove all trace of colouring material, such as peaty acids when collecting area is largely moorland, will undoubtedly, as indicated, find more and more use in industry —that is, filtering and purifying the entire supply for general process work, and not the boiler plant only.

It may be mentioned that a Paterson plant on these lines is also operating in India at the Jamshedpur Works of the Tata Iron and Steel Co., Ltd., and another notable installation now in progress of erection is at the Imperial Steel Works, Yawata, Japan (on the Island of Honshiu), which is now being extended to produce 750,000 tons of steel per annum, with plans for the eventual production of 1,000,000 tons.

IRON AND STEEL REPORT.

EXCEPT for a slight spurt in the foundry-iron branch, little has occurred in the way of development in the iron and steel trades during the past month. In the heavy steel branch, rollers have waited in vain for any important additions to order books. The construction of the new giant Cunarder on the Clyde will prove a welcome outlet for plates and other steel materials, but there is relatively little work in progress in other shipbuilding establishments, and altogether the consumption of steel in this direction is well below normal. Locomotive-building firms are also a good deal less busy than they were about six months ago, and the blight which for so long has overhung the constructional engineering industry continues, new contracts of any real weight being few and far between, and less than sufficient to make up for work being completed. Conditions in these important outlets for heavy steel materials are obviously far from satisfactory, and the general complaint of rollers is the paucity of forward contract buying.

One theory of the strictly hand-to-mouth scale of operations is that consumers are awaiting the outcome of the January meeting of the Steel Association, with the possibility of lower prices for home-produced steel materials or more advantageous terms under the rebate arrangements. So far as actual price movements during the past month are concerned, these have been confined to a slight weakening in quotations for acid and basic qualities of boiler plates, and also for small re-rolled bars. Controlled products have all been maintained at the rates which have been operative for so long now, joists being on offer at £8 10s. per ton, sections at £8 7s. 6d., tank plates at £8 17s. 6d., frame plates (including surface inspection charges) at £9 2s. 6d., and large-diameter bars at £9 7s. 6d.

A feature of the British markets for Continental iron and steel products of late has been a stiffening in the general range of prices after a series of falls which had brought quotations in many sections to below those ruling before the war. Judging from the fact that users in this country continued to abstain from following the rise to the extent of placing orders for bigger tonnages, there is no more confidence at the consuming end of the trade in the ability of Continental makers to maintain the higher rates than there is among sellers themselves, and at the moment prospects in this section are extremely uncertain. Within the past few days a Paris meeting of the Management Committee of the International Steel Cartel, pending a final decision, resolved to continue the present regime until June 30 of next year, and resolved also to reduce the output, subject to the approval of the participating groups, by from 25 to 30% during the first quarter of 1931. Prospects of immediate expansion in the world steel situation seem, therefore, to be regarded as not particularly bright among Continental producing interests.

Following upon the last price reduction by Midland foundry iron makers, a satisfactory development has been a slight though welcome improvement in forward buying operations, users in many instances filling potential needs up to the end of January, until when no further interference with price levels, in one direction or the other, is anticipated. Beyond then, however, there is little anxiety to go, for there is still a lack of confidence among consumers as to the stability of values. In one or two areas, notably in the Lancashire district, there has been a very slight expansion, compared with the experience of the past few months, in the rate at which pig iron has been going into consumption at some of the foundries, and this constitutes one of the few relatively bright patches in the iron and steel markets.

On the North-East coast the suggestion has been made that the Government should give credit to enable iron-masters to manufacture pig iron for stock against future demands, and it has been officially stated by the President of the Board of Trade that the suggestion is being fully inquired into by his Department.

MARKET PRICES

ALUMINIUM.

99% Purity	£85	0	0
Castings, 2.L5 Alloy	lb.	1/3–1/8	
„ 2.L8 „	„	1/4–1/9	
„ Silicon „	„	—	

ANTIMONY.

English	£36	0	0
Chinese	25	5	0
Crude	22	0	0

BRASS.

Solid Drawn Tubes	lb.	10½d.
Brazed Tubes	lb.	11½d.
Rods Drawn	„	1 d.
Wire	„	9d.
*Extruded Brass Bars	„	5½d.

COPPER.

Standard Cash	£49	5	0
Electrolytic	55	0	0
Best Selected	52	0	0
Tough	51	10	0
Sheets	84	0	0
Wire Bars	56	15	0
Ingot Bars	56	15	0
Solid Drawn Tubes	lb.	1	0
Brazed Tubes	„	1	0

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	£0	2	6
‡Ferro Tungsten	„	0	2	3
§Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	30	2	6
4-6% Carbon, scale 7/- per unit	„	23	0	0
6-8% Carbon, scale 7/- per unit	„	22	2	6
8-10% Carbon, scale 7/- per unit	„	21	17	6
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	„	32	17	6
§Guar. max. 1% Carbon, scale 13/6 per unit	„	36	10	0
§Guar. max. 0.7% Carbon, scale 15/- per unit	„	40	0	0
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	„	0	2	7
§Ferro-Vanadium 25-50%	„	0	12	8
§Spiegel, 18-20%	ton	7	5	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/- per unit	„	7	15	0
45/50% basis 45%, scale 5/- per unit	„	11	7	6
70/80% basis 75%, scale 7/- per unit	„	18	12	6
90/95% basis 90%, scale 10/- per unit	„	25	6	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	0	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
§Ferro Phosphorus, 20-25%	ton	15	17	6

FUELS.

Foundry Coke—					
S. Wales Export	£1	7	6 to	£1	15	0
Sheffield Export	0	16	6 to	0	17	0
Durham Export	1	4	0 to	1	6	0
Furnace Coke—						
Sheffield Export	£0	16	6 to	£0	17	0
S. Wales „		17	6 to	1	0	0
Durham	0	14	0 to	0	14	6

GUN METAL.

Commercial Ingots	£65	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	„	0	1	3

LEAD.

Soft Foreign	£15	15	0
English	17	5	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	5	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars		—	
Nut and Bolt Bars	9	0	0
Gas Strip	10	17	6
S. Yorks.—			
Best Bars	11	0	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/1
*Cored Bars	„	1/3
†Strip	„	1/1
†Sheet to 10 W.G.	„	1/1½
†Wire	„	1/2
†Rods	„	1/1
†Tubes	„	1/6
†Castings	„	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	17	0
Foundry No. 1	3	19	0
„ No. 3	3	16	6
N.E. Coast—			
Hematite No. 1	3	11	0
Foundry No. 1	3	6	0
„ No. 3	3	3	6
„ No. 4	3	2	6
Cleveland—			
Foundry No. 3	3	3	6
„ No. 4	3	2	6
Silicon Iron	3	6	0
Forge No. 4	3	2	0
N.W. Coast—			
Hematite	4	8	6
Midlands—			
N. Staffs Forge No. 4	3	6	0
„ Foundry No. 3	3	11	0
Northants—			
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
„ Foundry No. 3	3	11	0
West Coast Hematite	4	6	6
East „ „	4	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0 to	£7	10	0	
Bars, hammered, basis	£17	10	0 „	£18	10	0	
Blooms	£10	0	0 „	£12	0	0	
Keg steel	£32	0	0 „	£33	0	0	
Faggot steel	£20	0	0 „	£24	0	0	

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£40	0	0
„ Braziery	37	0	0
„ Wire		—	
Brass	30	0	0
Gun Metal	39	0	0
Zinc	8	10	0
Aluminium Cuttings	50	0	0
Lead	10	10	0
Heavy Steel—			
S. Wales	2	5	0
Scotland	2	10	0
Cleveland	2	6	0
Cast Iron—			
Lancashire	2	5	0
S. Wales	2	5	0
Cleveland £2 10 0 to	2	13	6
Steel Turnings—			
Cleveland	1	15	0
Lancashire	1	0	0
Cast Iron Borings—			
Cleveland	1	10	0
Scotland	1	10	0

SPELTER.

G.O.B. Official		—	
Hard	£11	10	0
English	14	17	6
India	12	10	0
Re-melted	12	15	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	10	0	0
„ „ (Marine) „	10	10	0
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	10	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	8	17	6
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic	9	12	6
Medium Basic	8	2	6
Soft Basic	6	10	0
Hoops	9	15	0
Manchester—			
Hoops	9	15	0
Scotland, Sheets 20 W.G.	9	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten. Ext as	lb.	3/-
Round and Squares, ¼ in. to ½ in.	„	3d.
Under ½in. to ⅞ in.	„	1/-
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/-

TIN.

Standard Cash	£114	2	6
English	115	15	0
Australian	117	12	6
Eastern	119	12	6
Tin Plates I.C. 20 × 14	box	17/-	
Block Tin Cash	£111	5	0

ZINC.

English Sheets	£24	0	0
Rods	28	0	0
Battery Plates	21	0	0

* McKechnie Brothers, Ltd., quoted Dec. 10. † C. Clifford & Son, Ltd., quoted Dec. 6. ‡Murex Limited, quoted Dec. 10.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices :—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 7s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £8 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 5s. 0d. to £8 10s. 0d; C. R. & C. A. Steel Hoops, £12 0s. 0d. to £13 0s. 0d; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Dec. 6.

§ Prices quoted Dec. 6, ex warehouse.

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ROLL GRINDING MACHINES

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Outstanding features:

Hydraulic traverse,
One-piece bed,
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Simple to operate,
Easy to maintain,
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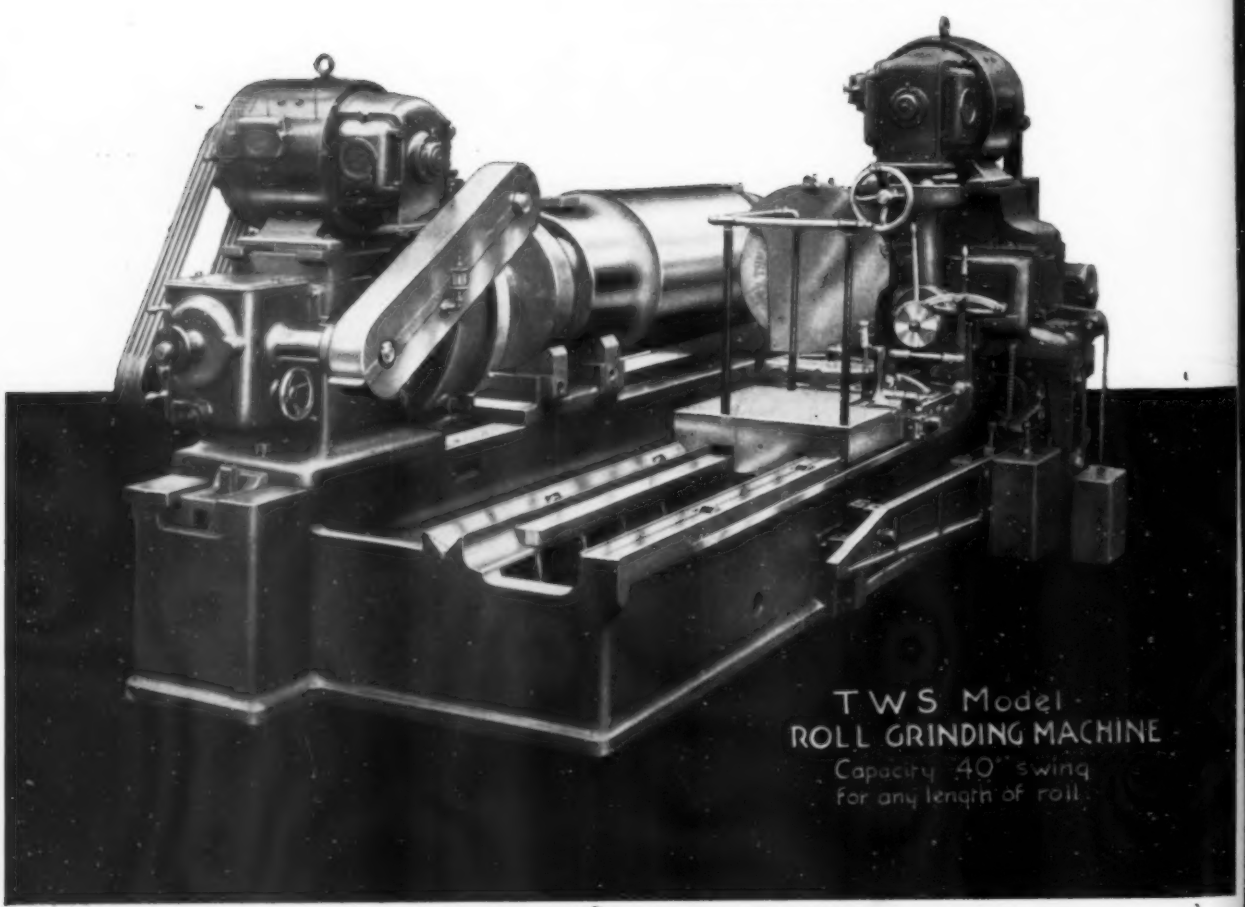
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